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Woods Hole Oceanographic Institution

Stratus Ocean Reference Station (20°S, 85°W) Mooring Recovery and Deployment Cruise STRATUS 8 R/V *Ronald H. Brown* Cruise 07-09 October 9, 2007–November 6, 2007

by

Sean Whelan[1], Jeff Lord[1], Carmen Grados[2], Lisan Yu[1], Luis Morales[3], Nancy Galbraith[1], Simon P. de Szoeke[4], Megan O'Leary[5], Robert Weller[1], Paul Bouchard[1], Tom Farrar[1], and Frank Bradley[6]

Woods Hole Oceanographic Institution,
Woods Hole, Massachusetts

December 2007

Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration under Grant No. NA17RJ1223 for the Cooperative Institute for Climate and Ocean Research (CICOR).

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
UOP Technical Report 2008-01

[1]Woods Hole Oceanographic Institution, Woods Hole, MA USA
[2]Instituto del Mar del Peru (IMARPE), Callao, Perú
[3] Instituto Nacional Oceanográfico del Ecuador (INOCAR), Guayaquil, Ecuador
[4] NOAA Earth System Research Laboratory (ESRL)
[5]Truro Central School, Truro, MA, USA
[6] CSIRO, Canberra, Australia

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Approved for Distribution:

Robert A Weller

Robert A. Weller, Chair

Department of Physical Oceanography

Abstract

The Ocean Reference Station at 20°S, 85°W under the stratus clouds west of northern Chile is being maintained to provide ongoing climate-quality records of surface meteorology (air-sea fluxes of heat, freshwater, and momentum), and of upper ocean temperature, salinity, and velocity variability. The Stratus Ocean Reference Station (ORS Stratus) is supported by the National Oceanic and Atmospheric Administration's (NOAA) Climate Observation Program. It is recovered and redeployed annually, with cruises between October and December.

During the October 2007 cruise on the NOAA ship *Ronald H. Brown* to the ORS Stratus site, the primary activities were recovery of the Stratus 7 WHOI surface mooring that had been deployed in October 2006, deployment of a new (Stratus 8) WHOI surface mooring at that site; in-situ calibration of the buoy meteorological sensors by comparison with instrumentation put on board the ship by staff of the NOAA Earth System Research Laboratory (ESRL); and observations of the stratus clouds and lower atmosphere by NOAA ESRL. Meteorological sensors on a buoy for the Pacific tsunami warning system were also serviced, in collaboration with the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA). The DART (Deep-Ocean Assessment and Reporting of Tsunami) carries IMET sensors and subsurface oceanographic instruments. A new DART II buoy was deployed north of the STRATUS buoy, by personnel from the National Data Buoy Center (NDBC) Argo floats and drifters were launched, and CTD casts carried out during the cruise.

The ORS Stratus buoys are equipped with two Improved Meteorological (IMET) systems, which provide surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming longwave radiation, precipitation rate, and sea surface temperature. Additionally, the Stratus 8 buoy received a partial pressure of CO_2 detector from the Pacific Marine Environmental Laboratory (PMEL). IMET data are made available in near real time using satellite telemetry. The mooring line carries instruments to measure ocean salinity, temperature, and currents.

The ESRL instrumentation used during the 2007 cruise included cloud radar, radiosonde balloons, and sensors for mean and turbulent surface meteorology. Finally, the cruise hosted a teacher participating in NOAA's Teacher at Sea Program

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ADCP	Acoustic Doppler Current Meter
CTD	Conductivity Temperature Depth
EPIC	Eastern Pacific Investigation of Climate
ETL	NOAA Environmental Technology Laboratory
ESRL	NOAA Earth System Research Laboratory (former ETL)
GPS	Global Positioning System
IMET	Improved Meteorological Systems
NOAA	National Oceanic and Atmospheric Administration
ORS	Ocean Reference Station
PMEL	Pacific Marine Environmental Laboratory
SBE	Sea Bird Electronics
SCS	Scientific Computer System
SHOA	Chilean Navy Hydrographic and Oceanographic Service
SST	Sea-Surface Temperature
UOP	Upper Ocean Processes Group
VMCM	Vector Measuring Current Meter
WHOI	Woods Hole Oceanographic Institution

Figure 1: Common abbreviations.

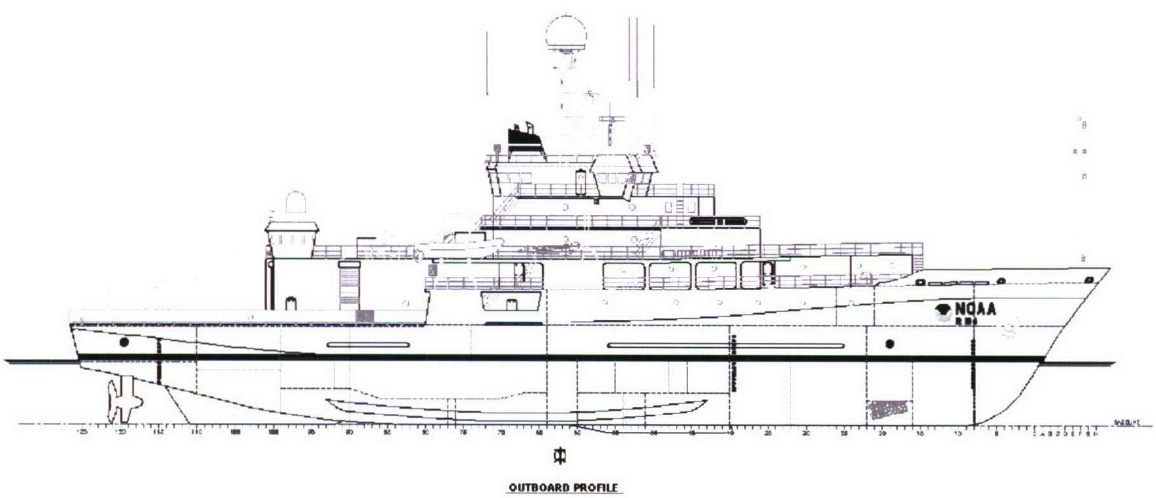

Figure 2: Side view of the NOAA Ship *Ronald H. Brown*.

1. Introduction

Background and Purpose

The presence of a persistent stratus deck in the subtropical eastern Pacific is the subject of active research in atmospheric and oceanographic science. Its origin and maintenance are still open to discussion. A better understanding of the processes responsible for it is desirable not only because the nature of air-sea interactions in this region could be of valuable and maybe unique interest, but also because the regional radiative budget, altered by the clouds, seems to introduce errors in the South Pacific SST field from current computer models. There is also a desire to monitor in-situ data because of the inability of satellites to cover the area under the stratus deck.

The Ocean Reference Station at 20°S, 85°W under the stratus clouds west of northern Chile is being maintained to provide ongoing, climate-quality records of surface meteorology, of air-sea fluxes of heat, freshwater, and momentum, and of upper ocean temperature, salinity, and velocity variability. The Stratus Ocean Reference Station (ORS Stratus) is supported by the National Oceanic and Atmospheric Administration's (NOAA) Climate Observation Program. It is recovered and redeployed annually, with cruises that have come between October and December.

During the October 2007 cruise of NOAA's R/V *Ronald H. Brown* (RHB) to the ORS Stratus site, the primary activities were recovery of the WHOI surface mooring that had been deployed in October 2006, deployment of a new WHOI surface mooring at that site, in-situ calibration of the buoy meteorological sensors by comparison with instrumentation put on board RHB by staff of the NOAA Earth System Research Laboratory (ESRL, formerly ETL), and observations of the stratus clouds and lower atmosphere by NOAA ESRL.

The ORS Stratus buoys are equipped with two Improved Meteorological (IMET) systems, which provide surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming longwave radiation, precipitation rate, and sea surface temperature. The buoy is also outfitted with a pCO_2 sampling system. The IMET data are made available in near real time using satellite telemetry. The mooring line carries instruments to measure ocean salinity, temperature, and currents. The ESRL instrumentation used during the 2007 cruise included cloud radar, radiosonde balloons, and sensors for mean and turbulent surface meteorology.

The Chief Scientist was Dr. Robert Weller, who is affiliated with the Woods Hole Oceanographic Institution. There were 15 people in the science party; whose list is given in Figure 3 below. Jochen Klinke from Oceanscience Group sailed from Charleston to Rodman.

	Name	Sex	Affiliation	Nationality
1	Robert Weller	M	WHOI	USA
2	Jeff Lord	M	WHOI	USA
3	Nan Galbraith	F	WHOI	USA
4	Sean Whelan	M	WHOI	USA
5	Lisan Yu	F	WHOI	USA
6	Megan O'Leary	F	NOAA TAS	USA
7	Chris Fairall	M	NOAA ESRL	USA
8	Simon De Szoeke	M	NOAA ESRL	USA
9	Sergio Pezoa	M	NOAA ESRL	USA
10	Edward Bradley	M	CSIRO	Australia
11	James Coleman	M	NDBC/SAIC	USA
12	Russel Spiers	M	NDBC/SAIC	USA
13	Luis Morales	M	INOCAR	Ecuador
14	Jorge Piana	M	DHN	Peru
15	Carmen Grados	F	IMARPE	Peru

Figure 3: Stratus 2007 science party.

Ronald H Brown sailed from Charleston on October 9. The cruise track is shown in Figure 4. A stop was made in Miami to drop off a technician servicing the ship's navigation equipment. Then the ship proceeded to the northern end of the Panama Canal, reaching there the 15th of October. The ship transited the canal and reached Rodman, Panama, on the 16th. At Rodman, Jochen Klinke (Oceanscience Group) went ashore and the remainder of the science party came aboard. RHB sailed south along the west coast of South America. Sampling began once in Ecuadorian waters and continued through Peruvian waters unit reaching the SHOA DART buoy. Clearance had been obtained from Ecuador and Peru. Underway CTD (UCTD) sampling was done, as well as data collection using the RHB's underway oceanographic and meteorological sensors and sampling by the group from NOAA ESRL.

At the SHOA DART buoy, meteorological sensors were recovered and a new set mounted in their place. The RHB sailed west toward the WHOI surface mooring, continuing underway sampling. RHB deployed the Stratus 8 buoy first and then recovered the Stratus 7 buoy. Shipboard and buoy sensors were compared while at the WHOI Stratus Ocean Reference Station (ORS) site.

After leaving the Stratus ORS site, an NDBC DART buoy was deployed. Then the ship steamed toward Puerto Ayora in the Galapagos, entering the port on November 6, 2008. Underway sampling stopped outside the Galapagos restricted region. Along the way 10 Argo profiling floats (provided by Breck Owens), 4 profiling buoys with oxygen (provide by Gerard Eldin), and

15 NOAA surface drifters provided by NOAA AOML were deployed. Radiosondes were launched and atmospheric observations made by Chris Fairall's group from NOAA ESRL and Frank Bradley (CSIRO, Canberra, Australia). On several legs of the transit, the UCTD was deployed to collect upper ocean temperature and salinity data.

Equipment was initially shipped to Charleston and placed on the RHB there. Final check out was done in Charleston and while underway. Data was downloaded from instruments recovered from Stratus 7 and hand-carried back. The Stratus 7 mooring and the equipment loaded in Charleston was off loaded in San Diego in December and shipped home.

This report documents the work done to prepare for the cruise and the work done while at sea on the cruise.

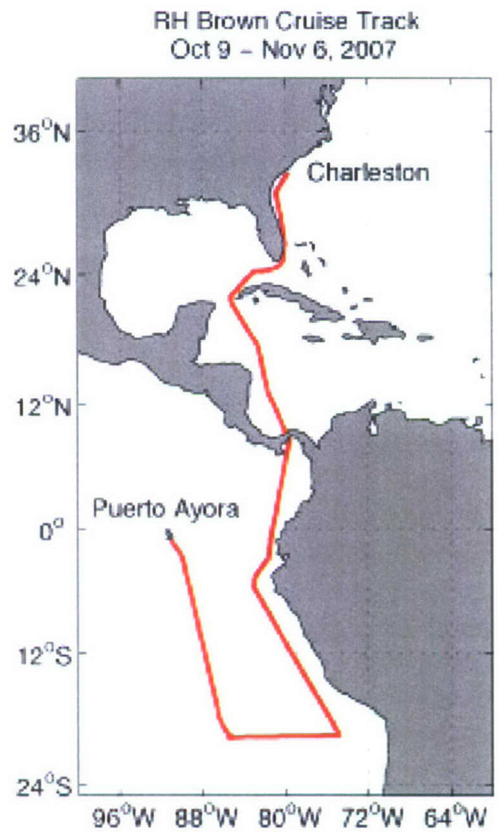

Figure 4: Cruise track.

2. Pre-cruise Operations

a. Staging and Loading Charleston

On October 4, 2007, two flatbed trucks and a 53-foot box truck were loaded with the STRATUS buoy, mooring components, support gear, and spares. Delivery of the cargo was scheduled for October 5-6. WHOI personnel traveled to Charleston on October 5-6 to meet the cargo and begin the buoy build up and cruise preparations.

The 53-foot box truck arrived at the pier in Charleston on the afternoon of October 5. The truck was unloaded, and most components were craned onto the deck. This truck contained most of the lab equipment and components to build up and test the buoy tower and meteorological systems. Work began on buoy assembly and lab setup.

On October 6, the two flatbed trucks with the remaining gear arrived in Charleston. A crane was hired to position the containers and heavy equipment onto the ship. At the same time the equipment was being loaded on the ship, personnel were setting up computers and equipment in the lab. The flux system was mounted on the bow mast, Short Wave Radiation modules were set up for testing on the bow, and all GPS and Argos receivers were set up and antenna wires run throughout the ship.

On October 7, the build up of the buoy well and tower was completed, and the system was checked for proper function. The buoy was moved into an empty parking lot to perform a check of the compasses on the buoy's wind modules.

Transmissions from the instruments on the buoy were received with an Alpha Omega uplink receiver to check the validity of data as part of the final burn-in. The buoy was then loaded onto the ship. RHB departed from Charleston on October 9, 2007, and arrived in Rodman, Panama, on October 16, 2007. The ship anchored west of the canal zone, and a work boat was hired to transport remaining science personnel to the ship and to take Jochen Klinke ashore. As soon as the science party boarded, the ship departed to begin the first leg of the STRATUS 8 cruise.

b. Sensor Evaluation

Testing for the ASIMET units deployed on the Stratus 8 buoy began on June 27, when the primary loggers were powered up, and continued until the instruments were powered down and disassembled for shipping on September 21. A third logger, SN L-05, was also instrumented and underwent burn-in as a spare unit starting on July 25. Data quality of the three systems was monitored beginning in late June and early July for the primary units. Modules that did not perform well during burn in were replaced.

Once the buoy was reassembled in Charleston, a last phase of the instrument check-out for meteorological sensors began. Using an Alpha Omega Uplink Receiver on the ship, hourly averaged data transmitted by the loggers to the Argos satellite system were continuously monitored until after the buoy was deployed.

All instruments were performing well when the buoy was disassembled for shipping to Charleston. Plots of both the internally recorded 1-minute data and the hourly averaged satellite transmitted data during the burn-in period show some disagreement between some pairs of sensors, documented here in plots of one day near the end of the burn in. Wind, relative humidity, and barometric pressure data is shown for September 19, the day in which the buoy was outdoors and undisturbed. Radiometer data is shown for September 14, the last sunny day of the burn in. Data from precipitation sensors are shown on July 27, the day they were tested. The SBE-37 SSTs were found to be functioning as expected. We usually see some effect of RF noise caused by the Argos PTT transmitters, especially in burn-in data; this effect is almost always much less after deployment. Figures 5, 6, 7, and 8 show snapshots of module performance.

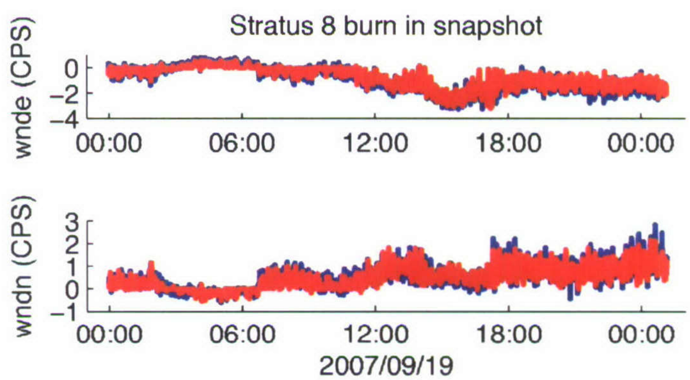

Figure 5: Wind sensors agreed to within .02 meters per second.

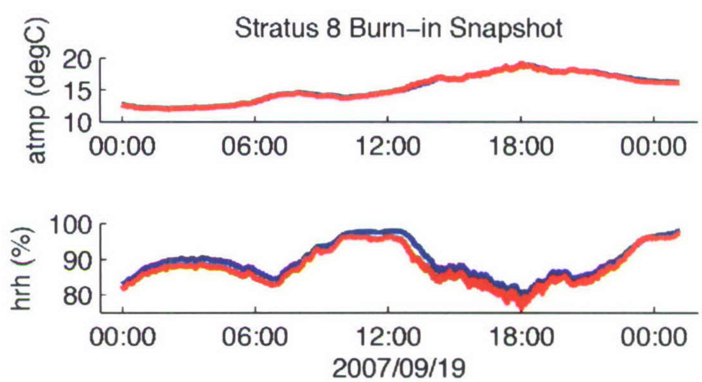

Figure 6: Air temperature and relative humidity comparison. HRH showed a persistent offset.

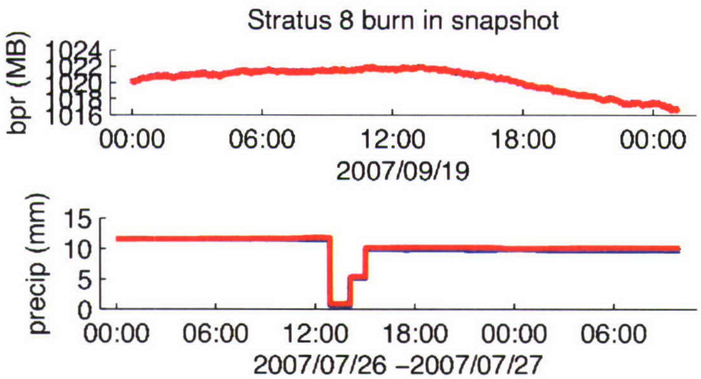

Figure 7: Barometric pressure and precipitation comparisons. The PRC sensors were filled and drained on July 27. During natural rain events after buoy was re-assembled on the *Ron Brown*, rain rates from the two Asimet units agreed within 1 mm/hour, according to Argos hourly averaged data.

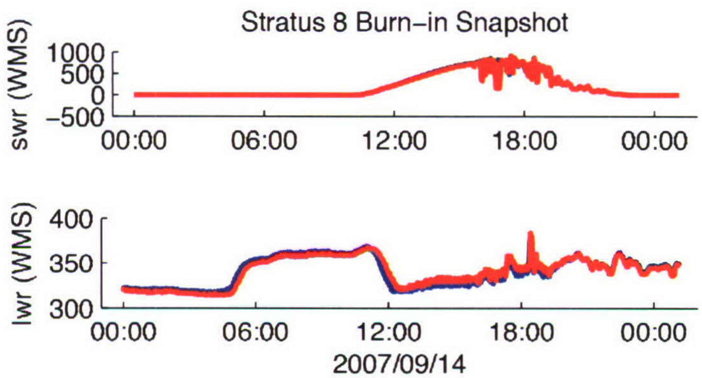

Figure 8: Barometric pressure and precipitation comparisons

Buoy spins were conducted and were found to meet expectations. The buoy spin is a procedure to check the compass on the buoy. A visual reference direction is first set using an external compass. The buoy is then oriented successively at 8 different angles and the vanes of the anemometers are visually oriented towards the reference direction, and blocked. Wind is recorded for 15 minutes at the end of which the average compass and wind direction is read. The sum should correspond to the reference heading, within errors due to approximations in orientation, compass precision, and any deformation of the magnetic field due to the buoy metallic structure. A first buoy spin was made in Woods Hole and a second one in Charleston. STRATUS 8 wind deployment consisted of: System 1 (L-01) Sonic Wind 203, System 2 (L-02) R.M. Young Wind 211, Stand alone R.M. Young wind 343.

3. Stratus-8 Mooring Description

a. Mooring Design

The buoys used in the Stratus project are equipped with surface meteorological instrumentation, including two Improved Meteorological (IMET) systems. The mooring line also carries subsurface instrumentation that measures conductivity and temperature and a selection of acoustic current meters and vector measuring current meters.

The WHOI mooring is an inverse catenary design utilizing wire rope, chain, nylon and polypropylene line and has a scope of 1.25 (scope is defined as slack length/water depth). The Stratus 8 surface buoy has a 2.7-meter diameter foam buoy with an aluminum tower and rigid bridle. The design of these surface moorings takes into consideration the predicted currents, winds, and sea-state conditions expected during the deployment duration.

b. Buoy Surface Instrumentation

i. ASIMET: Figure 9 shows Stratus 8 ASIMET composition.

Stratus 8 Serials/Heights

System 1

Module	Serial	Firmware Version	Height Cm
Logger	L-01	LOGR53 V2.70	
HRH	222	VOS HRH53 V3.2	230
BPR	502	VOS BPR53 V3.3 (Heise)	234
SWND	203	V4.03cf	280
PRC	502	VOS PRC53 V3.4	240
LWR	505	VOS LWR53 V3.5	282
SWR	214	VOS SWR53 V3.3	282
SST	1834		-151
PTT	14612	24337, 27970, 27971	

System 2

Module	Serial	Firmware Version	Height Cm
Logger	L-02	LOGR53 V2.70	
HRH	225	VOS HRH53 V3.2	230
BPR	210	VOS BPR53 V3.3 (Heise)	235
WND	211	VOS WND53 V3.5	272
PRC	506	VOS PRC53 V3.4	240
LWR	502	VOS LWR53 V3.5	282
SWR	223	VOS SWR53 V3.3	282
SST	1840		-151
PTT	14709	09805, 09807, 09811	

Stand-Alone Module(s)

Module	Serial	Firmware Version	HeightCm
WND	343	VOS WND53 V3.5	272

Figure 9: Stratus 8 ASIMET composition.

ii. Floating SSTs

A Sea-Bird SBE-39 was placed in a floating holder (a buoyant block of syntactic foam that slides up and down along 3 stainless steel guide rods with stainless springs) in order to sample the sea temperature as close as possible to the sea surface. The Sea-Bird model SBE-39 is a small, lightweight, durable and reliable temperature logger. A Brancker TR-1050 temperature was fixed to the floating SST frame for comparison. Figure 10 shows the Stratus 8 floating SST composition.

Instrument	Serial
SBE39	1446
TR-1050	10983

Figure 10: S8 Floating SST

iii. Bridle SSTS

Two Sea-Bird SBE 37s are mounted to the bottom of the buoy hull at approximately 1 meter depth. These instruments are part of the IMET system and provide near-real time data of temperature and conductivity near the sea surface. Figure 11 shows the Stratus 8 Bridle SST composition.

Instrument	Serial
SBE37_SST	1840
SBE37_SST	1834

Figure 11: S8 Bridle SST

iv Subsurface Argos Transmitter

A Subsurface Mooring Monitoring Beacon (SMM 500), built by Sensoren Instrumente Systeme GnbH (SiS), was mounted upside down on the bottom of the buoy. This is a backup recovery aid in the event that the mooring parts and the buoy capsizes and is shown in Figure 12.

Serial	Identification
22	11427

Figure 12: S8 Subsurface Argos Transmitter

v. Telemetry

Each ASIMET module onboard the buoy samples data every minute and records it on a dedicated flashcard. The logger receives and stores this data. It also computes hourly averages for Argos transmissions. These Argos transmissions can be picked up as well by an Alpha Omega Uplink receiver directly from the Argos antenna on the buoy. The hourly averages help monitoring the status of instruments and quality of data they provide. Figure 13 shows the Argos composition for Stratus.

Logger	Serial	Identifications
L-01 PTT	14612	24337, 27970, 27971
L-02 PTT	14709	09805, 09807, 09811

Figure 13: S8 PTTs

vi. pCO2

Upwelling in the equatorial Pacific leads to enhanced productivity and degassing of CO_2 across a region ranging from the coast of South America to past the International Date Line. The vast area affected makes this region a significant contributor to global biogeochemical cycles. Variability in the South American upwelling region has been linked to a wide range of

ecosystem and biogeochemical changes. Understanding this variability is a primary reason for the ongoing work at the Stratus site. The pCO2 system on the Stratus mooring is a component in the OceanSITES moored pCO2 network.
CO2 measurements are made every three hours in marine boundary layer air and air equilibrated with surface seawater using an infra-red detector. The detector is calibrated prior to each reading using a zero gas derived by chemically stripping CO2 from a closed loop of air and a span gas (414 ppm CO2) produced and calibrated by NOAA's Earth System Research Laboratory (ESRL).

PMEL pCO2 system 0011 was used for this deployment.

A summary file of the measurements is transmitted once per day and plots of the data are posted in near real-time to the web. To view the daily data, visit the NOAA PMEL Moored CO2 Website: http://www.pmel.noaa.gov/co2/moorings/stratus/stratus_main.htm.
Within a year of system recovery, the final processed data are submitted to the Carbon Dioxide Information Analysis Center (CDIAC) for release to the public.

vii. Sonic Wind

A GILL Sonic Wind Sensor, Figure 14, was incorporated into the STRATUS 8 buoy. The anemometer measures the time taken for an ultrasonic pulse to travel from one transducer to the opposite transducer and then compares it with the time taken for another pulse to travel in the opposite direction. Likewise, differences are measured between other pairs of transducers allowing calculations of both wind speed and direction.

Serial	Firmware
203	V4.03cf

Figure 14: S8 Sonic Wind

viii Wave Package

Technical aspects of the NDBC wave package

The WAMDAS wave system used on the STRATUS 8 buoy, is made by Neptune Sciences and acquired from NDBC. This includes wave measurements, GPS positions, and GPS times. It utilizes a 3-axis motion pack made by MicroStrain Inc. The WAMDAS is capable of transmitting and storing data. The transmitted data is sent via Iridium communications on an hourly basis. This message is ultimately transmitted to NDBC where the data are subjected to automated quality-control checks and then posted on the NDBC web site. The data is stored in raw and processed format on a 1 GB compact flash card in the instrument.

Motion sensor

The motion sensor is a 3DM-GX1 Gyro Enhanced Orientation Sensor version 3.1.01 capable of communicating with a host system or alone via RS232 serial communications. The 3-axis sensor is used in the polled mode where the host system requests axis information, processes it, and stores the data. A complete description of the 3DM-GX1 can be found at MicroStrain Inc.'s web site.

Processor & logger
The onboard computer is a Persistor Instruments Inc., Persistor CF2, 68332 Based computer system. It also utilizes the Texas Instruments ADS8344 16 bit, 8 channel A/D converter and a Maxim RS232 driver for two TPU UARTs.

Physical mounting
The mounting of the sensor, electronics box, and antennas are in different locations on the buoy. The sensor is mounted inside the buoy well approximately at the waterline and in the center of the buoy. The sensor is also 6" below any batteries or electronics in the well. This allows for minimizing magnetic interference. The electronics housing is mounted inside the buoy well above the batteries and MET loggers (STRATUS 8 only). A longer sensor cable is required to reach between the sensor and the electronics box. The GPS and Iridium antennas are mounted on the top of the wind vane above the radar reflector. Figures 15 and 16 show installation.

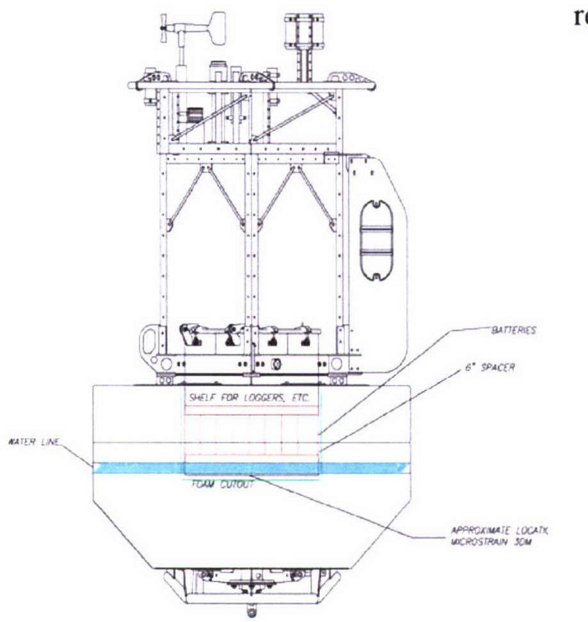

Figure 15: S8 Wave Component Locations

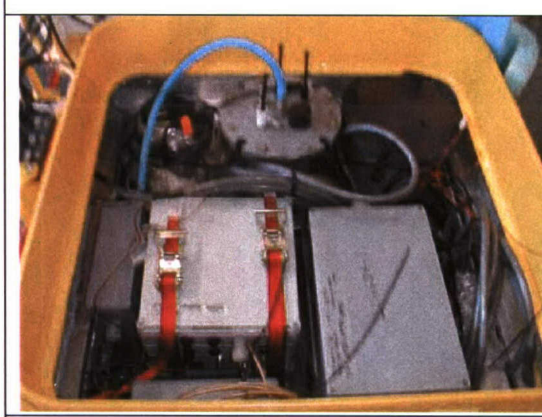

Figure 16: S8 Sonic Wind Buoy Well Configuration

Instrument preparation

*Magnetometer spin*A hard-iron calibration is required for the 3DM-GX1 sensor. The hard-iron calibration is an attempt to correct for the magnetic field caused by the buoy assembly and electronics. This was performed with all electronics and battery packs in place in the well and powered up. This was done to simulate the actual configuration during deployment. On the "STRATUS 8" buoy, mounted and powered up, are 2 each complete ASIMET systems with ARGOS transmitters and antennas, a PCO2 system, and a stand alone RM Young wind instrument. The buoys were hung in Clark South high bay with an overhead crane (see below). The spin is comprised of 2 complete revolutions at 1 rev. per minute. Data is then acquired, processed, and then applied to X, Y, and Z Iron Calibration Offsets. The procedure is described in SAIC's, Science Applications International Corporation; document "ETP 07-003, Rev. B". Once the procedure is completed the offset values are recorded and a copy of the EEPROM map where the values are store is saved for future reference

Figure 17: S8 Rigging of the assembled buoy for buoy spin (or 'hard-iron calibration')

Set magnetic deviation
The WAMDAS has the capability of utilizing the magnetic variation, for a certain location, to calculate directions and locations. The magnetic variation needs to be specified before testing and deploying. The magnetic variation can be found at web link (http://www.ngdc.noaa.gov/seg/geomag/jsp/struts/IgrfWmmLocationSwitch). Next, see SAIC's document ETP 07-007, Rev. A, section 7.2.4, to enter the magnetic offsets, scales, and variation into the WAMDAS.

Testing and recording values
Some basic testing shown in Figure 17 has been performed on the tilt and compass aspects of the WAMDAS.

The X and Y axis tilts were checked by first placing the buoy on a flat surface. Next, the X axis was tilted clockwise approximately 5 degrees, then the X, Y, and Z values were recorded. Second, the X axis was tilted counter-clockwise approximately 5 degrees, then the X, Y, and Z values were recorded. Next, the Y axis was tilted clockwise approximately 5 degrees, then the X, Y, and Z values were recorded. Finally, the Y axis was tilted counter-clockwise approximately 5 degrees, then the X, Y, and Z values were recorded. The tilts were checked with a digital level which has an accuracy of +/- .1 degrees. This step may not need to be performed for every deployment, but we should continue to do this as a check of the instrument setup until we are more comfortable with the instrument.

The equivalent of a buoy spin was performed to check the Z axis, also known as "Yaw". The buoy was checked at 8 different magnetic headings. First, the buoy (X axis) was oriented to

point to North. Next, the WAMDAS was put into a 3DM-GX1 test mode, and the Yaw value was recorded. Next the buoy was moved clockwise by 45 degrees, and the process was repeated. After 8 different points, the spin was completed.

Burn in

Before the buoy can be deployed, as part of it's testing, the electronics were powered up and run for a lengthy period of time in a process we refer to as a burn in. During this period, data were collected and transmitted while the buoy was placed outside. Periodically, the data were extracted by removing the compact FLASH card and removing the files. Next, the data were examined and any issues would be addressed. The transmitted data goes through NDBC data control and then is posted online. Figure 18 shows components and serials for the wave package.

Component	Serial
NDBC#	24360
WAMDAS	4002
3DM-GX1	4100-1845
Iridium Modem	24536
ID	WHOI1

Figure 18: S8 Wave Components

c. Subsurface Instrumentation

The following sections describe individual instruments on the buoy bridle and mooring line. Where possible, instruments were protected from being fouled by fishing lines using "trawl-guards" designed and fabricated at WHOI. These guards are meant to keep lines from hanging up on the in-line instruments.

Before a buoy launch and after its recovery, different physical signals are imprinted in the instruments records at determined time. This reveals the possible presence of a drift in the internal clock of instruments. Temperature and salinity sensors are plunged into a large bucket filled with ice and fresh water for about an hour. VMCM rotors are spun and then blocked.

i.VMCMs

The VMCM has two orthogonal cosine response propeller sensors that measure the components of horizontal current velocity parallel to the axles of the two-propeller sensors. The orientation of the instrument relative to magnetic north is determined by a flux gate compass. East and north components of velocity are computed continuously, averaged and then stored. All the VMCMs deployed from Stratus 4 onward have been next generation models that have newer circuit boards and record on flash memory cards instead of cassette tape. Temperature was also recorded using a thermistor mounted in a fast response pod, which was mounted on the top end cap of the VMCM. Figure 19 shows VMCM deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
VMCM	10	100	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	29	145	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	30	183	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	57	235	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	58	290	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	66	350	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	68	852	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00
VMCM	76	1555	1min	15-Oct-07	1:00:00	10/26/07 18:17	10/26/ 18:19:00

Figure 19: S8 VMCMs

ii. RDI Acoustic Doppler Current Profiler

The RD Instruments (RDI) Workhorse Acoustic Doppler Current Profiler (ADCP, Model WHS300-1) is mounted looking upwards on the mooring line. The RDI ADCP measures a profile of current velocities. Figure 20 shows ADCP deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
ADCP	1220	135	60 Min	15-Oct-07	1:00:00	10/18/07 19:41	10/18/07 20:50

Figure 20: S8 ADCPs

iii. Nortek

The Nortek Aquadopp current profiler uses Doppler technology to measure currents. It has 3 beams tilted at 25 degrees and has a transmit frequency of 1 MHz. The internal tilt and compass sensors give current direction. Figure 21 shows NORTEK deployment infromaton.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
NORTEK	1666	15	900 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40
NORTEK	1688	20	900 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40
NORTEK	2064	45	900 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40
NORTEK	2082	55	900 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40
NORTEK P	333	10	3600 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40

Figure 21: S8 Nortek

iv SonTek Argonaut MD Current Meter

SonTek Argonaut MD current meters have been used in the upper portion of the mooring line. The three-beam 1.5Mhz single point current meter is designed for long term mooring deployments, and can store over 90,000 samples. Figure 22 shows Sontek deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
SONTEK P	D193	33	600 Sec	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40

Figure 22: S8 Sontek

v. SBE-39 Temperature Recorder

The Sea-Bird model SBE-39 is a small, light weight, durable and reliable temperature logger. It is a high-accuracy temperature (pressure optional) recorder with internal battery and non-volatile memory for deployment at depths up to 10,500 meters (34,400 feet). Figure 23 shows SBE-39 deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
SBE39	0203	25	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	0721	35	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3423	70	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3434	77.5	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3435	92.5	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3436	115	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3437	175	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3438	400	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	3439	450	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE39	1446	FSST	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40

Figure 23: S8 SBE39s

vi. SBE37 MicroCat Conductivity and Temperature Recorder

The MicroCat, model SBE37, is a high-accuracy conductivity and temperature recorder with internal battery and memory. It is designed for long-term mooring deployments and includes a standard serial interface to communicate with a PC. Its recorded data are stored in non-volatile FLASH memory. The temperature range is -5° to +35°C, and the conductivity range is 0 to 6 Siemens/meter. The pressure housing is made of titanium and is rated for 7,000 meters. The instruments were mounted on in-line tension bars and deployed at various depths throughout the moorings. The conductivity cell is protected from bio-fouling by the placement of antifoulant cylinders at each end of the conductivity cell tube. Figure 24 shows SBE 37 deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
SBE37	1901	2	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1902	3.7	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1903	7	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1905	16	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1907	30	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1910	40	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	1912	62.5	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	2011	85	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28
SBE37	3639T	130	5 min	15-Oct-07	1:00:00	10/17/07 16:19	10/17/07 17:28

Figure 24: S8 SBE37s

vii. SBE16 SeaCat Conductivity and Temperature Recorders

The model SBE 16 SeaCat was designed to measure and record temperature and conductivity at high levels of accuracy. Powered by internal batteries, a SeaCat is capable of recording data for periods of a year or more. Data are acquired at intervals set by the user. An internal back-up battery supports memory and the real-time clock in the event of failure or exhaustion of the main battery supply. These were mounted on in-line tension bars and deployed at various depths throughout the moorings. The conductivity cell is protected from bio-fouling by the placement of antifoulant cylinders at each end of the conductivity cell tube. Figure 25 shows SBE 16 deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
SBE16	927	160	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE16	928	190	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE16	993	220	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE16	994	250	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40
SBE16	1877	310	5 min	15-Oct-07	1:00:00	10/17/07 13:28	10/17/2007 14:40

Figure 25: S8 SBE16s

viii. Brancker XR-420 Temperature and Conductivity Recorder

The Brancker XR-420 CT is a self-recording temperature and conductivity logger. The operating temperature range for this instrument is -5° to 35°C. It has internal battery and logging, with the capability of storing 1,200,000 samples in one deployment. A PC is used to communicate with

the Brancker via serial cable for instrument set-up and data download. Figure 26 shows XR420 deployment information.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
XR420	10515	2	5 min	15-Oct-07	1:00:00	10/19/07 11:48	10/19/07 13:40

Figure 26: S8 XR420

ix . Acoustic Release

The acoustic release used on the Stratus 8 mooring is an EG&G Model 8242. This release can be triggered by an acoustic signal and will release the mooring from the anchor. Releases are tested at depth prior to deployment to ensure that they are in proper working order. Figure 27 shows Stratus 8 acoustic releases.

Instrument	Serial
Model 8242	30846
Model 8242	31269

Figure 27: S8 Releases

d. Antifouling Coatings

Previous moorings have been used as test beds for a number of different antifouling coatings. The UOP group has moved from organotin-based antifouling paints to products that are less toxic to the user and more environmentally friendly. Test results have led the Upper Ocean Process group to rely on E Paint Company's SUNWAVE as the antifouling coating used on the buoy hull, and EPaint ZO for most of the instruments at 70 meters depth or above. A proprietary formula, called Bio-Grease, was developed for use on the ADCP/ADCM transducers.

Instead of the age-old method of leaching toxic heavy metals, the patented E Paint approach takes visible light and oxygen in water to create peroxides that inhibit the settling larvae of fouling organisms. Photo generation of peroxides and the addition of an organic co-biocide, which rapidly degrades in water to benign by-products make E Paint an effective alternative to organotin antifouling paints. These paints have been repetitively tested in the field, and show good bonding and antifouling characteristics.

SUNWAVE is a two-part, water-based, antifouling coating that offers a truly eco-friendly approach to controlling biofouling. The product claims superior adhesion and durability. Previous results have proven SUNWAVE as a viable alternative to organotin, copper, and other more toxic coatings.

Figure 28 shows what antifouling methods were used on the STRATUS 8 buoy and subsurface instruments.

Stratus 8 Anti Fouling Applications

Depth	Instrument	Anti Fouling Applied
Surface	Buoy Hull	E-Paint, Sunwave, 6 coats
Surface	Floating SST and Fixed SST	E-Paint ZO, 2 heavy coats
1 M	SBE 37 – SST 1 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
1 M	SBE 37 – SST 2 (C/T)	Copper tape over plastic tape on body, w ZO on sensor tube and shield
2 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
2 M	XR 420 – (CT)	E-paint ZO w/adjunct, 2 heavy coats
3.7 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
7 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
10 M	NORTEK ADCP	E-paint ZO over tape on body, copper tape on upper 6" near transducer heads. ZO on seams, clamps, and top. Bio-grease on transducer heads.
15 M	NORTEK ADCM	Copper foil over tape on body, ZO on seams and clamps. Bio-grease on transducer heads.
16 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
20 M	NORTEK ADCM	Copper foil over tape near transducer heads, ZO over tape on body & at seams near heads. Bio-grease on transducer heads
25 M	SBE 39 (Temp)	E-paint ZO w/adjunct, 2 heavy coats
30 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
33 M	SONTEK ADCM	ZO on top 4" near transducer heads
35 M	SBE 39 (Temp)	E-paint ZO w/adjunct, 2 heavy coats
40 M	SBE 37 (C/T)	E-paint ZO w/adjunct, 2 heavy coats
45 M	NORTEK ADCM	ZO on top 6", no tape
55 M	NORTEK ADCM	ZO on top 6", no tape
62.5 M	SBE 37 (C/T)	E-paint ZO w/adjunct, just around sensor and guard

Figure 28: S8 Antifouling

4. Stratus 8 Mooring Deployment

a. Deployment Operations

The Stratus 8 surface mooring was set using a two-phase mooring technique. Phase 1 involves the lowering of approximately 50 meters of instrumentation followed by the buoy, over the port side of the ship. Phase 2 is the deployment of the remaining mooring components through the A-frame on the stern.

The TSE winch drum was pre-wound with the following mooring components listed from deep to shallow:

- 200 m 7/8" nylon – nylon to wire shot
- 100 m 3/8" wire - nylon to wire shot
- 300 m 3/8" wire
- 200 m 3/8" wire
- 500 m 3/8" wire
- 500 m 3/8" wire
- 38 m 7/16" wire – working wire

A tension cart was used to pre-tension the nylon and wire during the winding process.

The ship was positioned 8 nautical miles downwind and down current from the desired anchor site. An earlier bottom survey indicated this track would take the ship over an area with consistent ocean depth.

Prior to the deployment of the mooring, approximately 80 meters of 3/8" diameter wire rope was payed out to allow the end to be passed out through the center of the A-frame, around the aft port quarter and forward along the port rail to the instrument lowering area.

Four wire handlers were stationed around the aft port rail. The wire handlers' job was to keep the hauling wire from fouling in the ship's propellers and to pass the wire around the stern to the line handlers on the port rail.

To begin the mooring deployment, the ship hove to with the bow positioned with the wind slightly on the port bow. The crane boom was positioned over the instrument lowering area to allow a vertical lift of at lease six meters. All subsurface instruments for this phase had been staged in order of deployment on the port side main deck. All instrumentation had chain or wire rope shackled to the top of the instrument load bar or cage. A shackle and ring was attached to the top of each shot of chain or wire.

The first instrument segment to be lowered was a NORTEK current meter at 45m. This instrument had an 8.75 wire rope segment shackled into the top and bottom of its load bar. This segment of wire rope was shackled into the 36 meter working wire coming from the winch. The crane hook suspended over the instrument lowering area was lowered to approximately 1 meter off the deck. A sling was hooked onto the crane and passed through a ring to the top of the 3.66 meter shot of chain shackled to the top of the current meter.

The crane was raised so the chain and instrument were lifted off the deck. The crane slowly lowered the wire and attached mooring components into the water. The wire handlers positioned around the stern eased wire over the port side, paying out enough wire to keep the mooring segment vertical in the water. An air tugger with a chain hook was used to haul on the chain and take the load from the crane. A stopper was attached to the top link of the instrument array as a back up. The hook on the crane was removed. Lowering continued with 10 more instruments and chain segments being picked up and placed over the side.

The operation of lowering the upper mooring components was repeated up to the 7 meter MicroCat T/C. The load from this instrument array was stopped off using a slip line passed through a shackle in the chain approximately one meter above the MicroCat load bar. The 2 meter and 3.7 meter C/T instruments were shackled to hardware and chain connecting them to the universal joint on the bottom of the buoy. The vertical instrument array hanging in the water was joined to the two instruments attached to the bottom of the buoy.

The second phase of the operation was launching the buoy. Three slip lines were rigged on the buoy to maintain control during the lift. Lines were rigged on the buoy bottom, the tower and a buoy deck bail. The 30 ft. slip line was used to stabilize the bottom of the buoy at the start of the lift. The 50 ft. tower slip line was rigged to check the tower as the hull swung outboard. A 75 ft. buoy deck bail slip line was rigged to prevent the buoy from spinning as the buoy settled in the water. This is used so the quick release hook, hanging from the crane, could be released without fouling against the tower. The deck slip line was removed just following the release of the buoy. An additional line was tied to the crane hook to help pull the crane block away from the tower's meteorological sensors once the quick release hook had been triggered and the buoy cast adrift.

With three slip lines in place, the crane swung over the buoy. The quick release hook, with a 1" sling link, was attached to the crane block. Slight tension was taken up on the whip to hold the buoy. The ratchet straps securing the buoy to the deck were removed. The buoy was raised up and swung outboard as the slip lines kept the hull in check. The stopper line holding the suspended 45 meters of instrumentation was eased off to allow the buoy to take the hanging load. The lower slip line was removed first, followed by the tower slip line. Once the discus had settled into the water (approximately 20 ft. from the side of the ship), and the release hook had gone slack, the quick release was tripped. The crane swung forward to keep the block away from the buoy. The slip line to the buoy deck bail was cleared at about the same time. The ship then maneuvered slowly ahead to allow the buoy to come around to the stern.

The winch operator slowly hauled in the slack wire once the buoy had drifted behind the ship. The ship's speed was increased to 1/2 knot through the water to maintain a safe distance between the buoy and the ship. The bottom end of the shot of wire shackled to the hauling wire was pulled in and stopped off at the transom.

A traveling block was suspended from the A-frame using the heavy-duty air tugger to adjust the height of the block. The next instrument, a 55 meter depth Nortek current meter and pre-attached wire shot was shackled to the end of the stopped off mooring. The free end of the hauling wire was passed from the winch, through the block, and shackled to the free end of wire on the

Nortek. The hauling wire was pulled onto the TSE winch to take up the slack. The winch slowly took the mooring tension from the stopper lines.

The block was hauled up to about 8 feet off the deck, lifting the current meter off the deck as it was raised. By controlling the A-frame, block height, and winch speed, the instrument was lifted clear of the deck and over the transom. The winch was payed out to the next termination. The termination was stopped off using lines on cleats, and the hauling wire removed while the next instrument was attached to the mooring.

The next several instruments were deployed in a similar manner. When pulling the slack on the longer shots of wire, the terminations were covered with a canvas wrap before being wound onto the winch drum. The canvas covered the shackles and wire rope termination to prevent damage from point loading the lower layers of wire rope and nylon on the drum. This process of instrument insertion was repeated for the remaining instruments down to 1555 meters. When all the wire and nylon on the winch drum were payed out, the end of the nylon was stopped off to a deck cleat.

An H-bit cleat was positioned in front of the TSE winch and secured to the deck. The free end of the 3000 meter shot of nylon/polypropylene line, stowed in three wood-lined wire baskets was dressed onto the H-bit and passed to the stopped off mooring line. The shackle connection between the two nylon shots was made. The line handler at the H-bit pulled in all the residual slack and held the line tight against the H-bit. The stopper lines on the mooring were then eased off and removed.

The person handling the line on the H-Bit kept the mooring line parallel to the H-bit with moderate back tension. The H-bit line handler and one assistant eased the mooring line out of the wire basket and around the H-bit at the appropriate payout speed relative to the ship's speed.

When the end of the polypropylene line was reached, pay out was stopped and a Yale grip was used to take tension off the polypropylene line. The winch tag line was shackled to the end of the polypropylene line. The polypropylene line was removed from the H-Bit. The winch line and mooring line were wound up taking the mooring tension away from the stopper lines on the Yale grip. The stopper line was removed. The TSE winch payed out the mooring line until all but one meter of the polypropylene line was over the transom.

While the wire and nylon line were being payed out, the crane was used to lift the 88 glass balls out of the rag top container. These balls were staged fore and aft, in four ball segments, on the port side of the deck.

The 88 glass balls are bolted on 1/2" trawler chain in 4 ball (4 meter) increments. The first two sets of glass balls were dragged into position and shackled together. One end was attached to the mooring at the transom. The other end was shackled to the winch leader. The winch pulled the mooring line tight, stopper lines were removed, and the winch payed out until 7 of the eight balls were off the stern. Stopper lines were attached, the winch leader was removed, and the process repeated until all 88 balls were deployed.

A 5-meter shot of chain was shackled to the last glass ball segment. The acoustic releases were shackled to the chain. Another 5-meter chain section was shackled to the releases. A 20-meter Nystron anchor pendant was shackled to that chain, and another 5 meter section of ½" chain was shackled to the anchor pendant. The mooring winch wound up these components until it had the tension of the mooring. The acoustic releases were laying flat on the deck.

The air tugger hauling line was passed through a block hung in the A-frame. A ½" chain hook was shackled to the end of the tugger line. The chain hook was attached to the mooring about two meters below the acoustic releases. The A-frame was positioned all the way in. The tugger line was pulled in and the releases were raised from the deck. As the winch payed out, the A-frame moved out and eased the release over the transom without touching the deck. The tugger payed out and the chain hook was removed.

The winch continued to pay out until the final 5-meter shot of chain was just going over the transom. A shackle and link was attached one meter up this segment of chain. A heavy-duty slip line was passed through the link and secured to two cleats on the deck. The winch payed out until tension was transferred to the slip line. The chain lashings were removed from the anchor. The end of the chain was removed from the winch and shackled to the anchor on the tip plate.

The starboard crane was shifted so the crane boom would hang over, and slightly aft of the anchor. Deck bolts were removed from the anchor tip plate. The crane was lowered and the hook secured to the tip plate bridle. A slight strain was applied to the bridle. The slip line was removed, transferring the mooring tension to the 1/2" chain and anchor. The line was pulled clear and the crane raised 0.5 meters lifting the forward side of the tip plate causing the anchor to slide overboard.

The deployment started at 12:00 (UTC), October 27th and the anchor was dropped at 18:30 (UTC). An hour after the anchor was dropped, an acoustic survey was made to locate the releases, placed 30 m above the anchor. Figure 29 lists the details of the Stratus 8 buoy deployment and Figure 30 is the Stratus 8 mooring as deployed.

Date	October 27, 2007
Time (anchor over)	18:27 UTC
Position at Anchor Drop	19°37.35'S, 85°22.54'W
Deployed by	Lord, Weller
Recorder	Galbraith
Cruise No.	RB-07-09
Depth (corrected)	4453.02 m
Anchor Position	19°37.215'S, 85°22.726'W

Figure 29: S8 Anchor Location

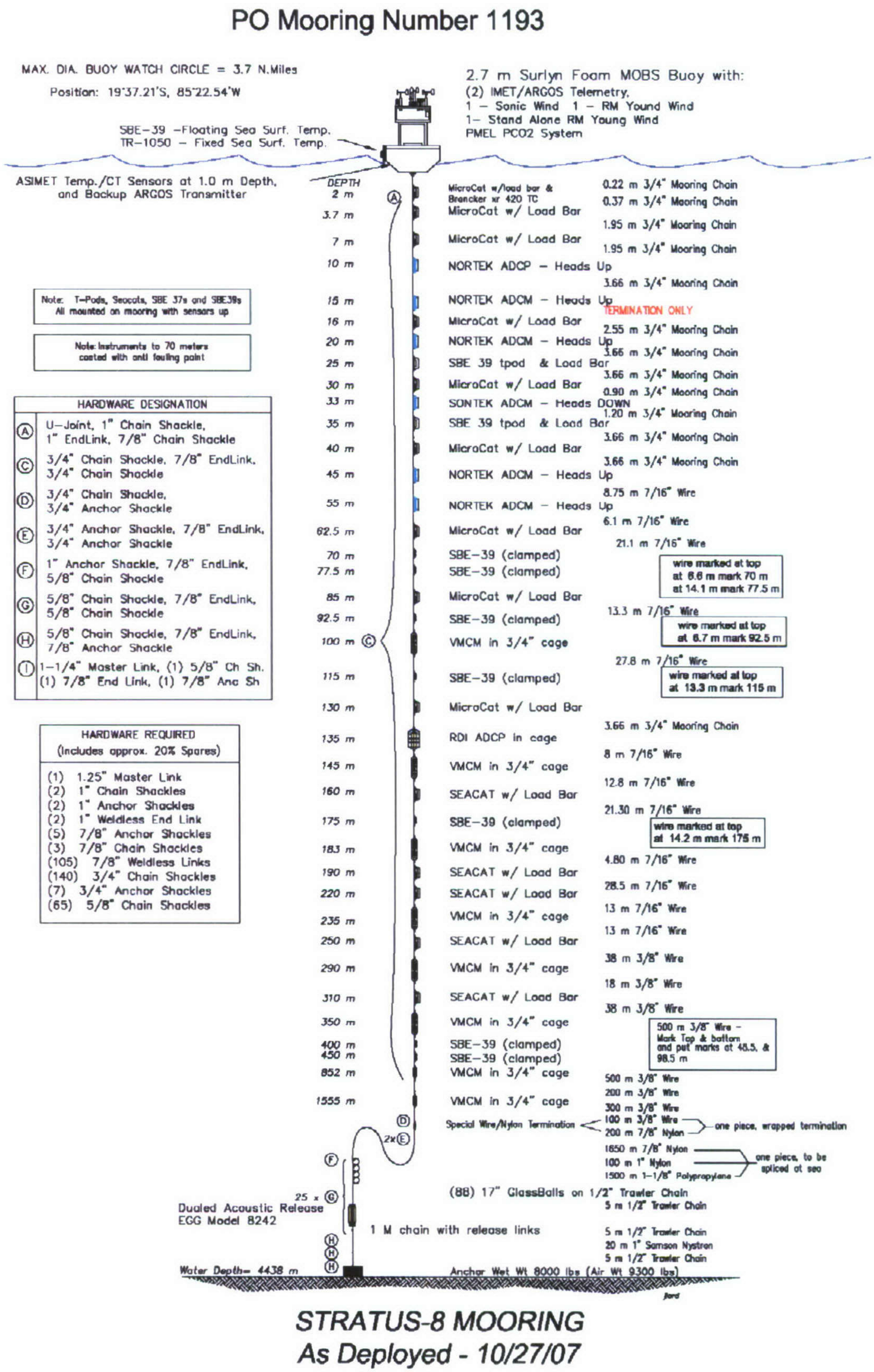

Figure 30: Stratus 8 Mooring Diagram Deployed

b. Anchor Survey

Following the anchor drop the *Brown* pulled to one side and allowed time for the anchor to reach the sea floor. At that point a three point acoustic survey was completed. Three points were selected at ranges approximately 2 miles from the estimated anchor location. The anchor was dropped at 19°37.355'S, 85°22.536'W. Corrected water depth at the site was 4453 meters.

At each of the three sites an Edgetech 8011A deck unit was used to communicate with one of the acoustic releases on the mooring. Signal travel time was recorded at each site. The locations of the ship during the ranging at each site and the travel time were then entered into Art Newhall's MATLAB program to generate an anchor position. The acoustic releases are 32 m above the anchor. The corrected depth used for the survey was 4406 m. The program works with the intersection of the three range arcs and calculates an anchor position on the bottom. Figure 31 shows the three arcs and anchor location chosen by the program.

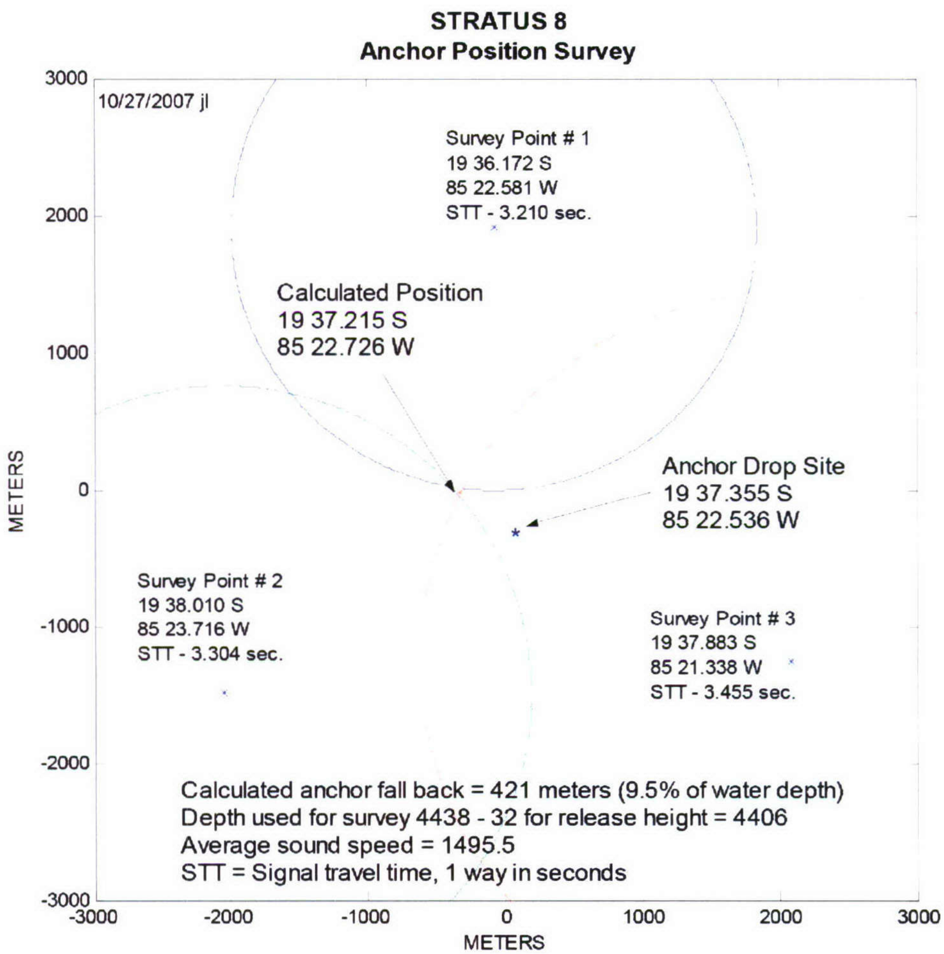

Figure 31: Stratus 8 Anchor Survey Plot

5. Stratus 7 Mooring Recovery

a. Recovery Operations

The Stratus 7 mooring was recovered on October 29, 2007. To prepare for recovery the *Ronald Brown* was positioned roughly 500 meters upwind from the anchor position. The release command was sent to the acoustic release to separate the anchor from the mooring line at 10:57 UTC. After about 40 minutes, the glass balls surfaced. Once the glass balls were on the surface, the ship approached the cluster of balls along the starboard side. The ship's small boat was used to tow the glass balls aft, where they could be secured to the mooring winch via a 25-meter working line and a 6' lift sling.

The winch leader was fed through the trawl block in the A-frame. A messenger line was thrown to the small boat, where the pendant/sling was attached and pulled back to the stern. The 25-meter working line was shackled into the winch leader. The *Ron Brown* pulled slowly ahead so the glass balls would be astern of the ship. At this time, it was discovered that the polypropylene mooring line was running under the ship. The winch hauled up to bring the cluster of glass balls over the stern. The three air tuggers were used to control the glass balls as they were pulled forward and lowered to the deck. Once all the glass balls were on board a stopper line was snapped into a sling link leading to the acoustic releases and then made fast to a deck cleat. The winch leader was payed out and disconnected. The winch leader was then hooked into the sling link above the acoustic releases. Once connected, the winch was used to haul the releases on board.

While one group began the disassembly and removal of the glass balls from the working area, the bosun worked on the polypropylene line that had fouled in the ships propeller. By retrieving segments of rope from both sides of the fouled segments, he was able to cut away the fouled section and still maintain control of both ends of the mooring line. The ship moved ahead, and the polypropylene leading to the rest of the mooring was tied onto the winch leader to hold mooring tension until the glass balls were clear of the working area. The glass balls were disconnected and hauled to the port side to be lifted by crane into the ragtop container on the 01 deck.

Once the balls were clear, a traveling block was hung from A-frame, using the large air tugger to adjust the height. The 1-1/8" polypropylene was led to the hydraulic capstan. The 1500m of 1-1/8" polypropylene, 100m of 1" nylon and three 1650m of 7/8" nylon were hauled in and placed in 3 wire baskets.

Hauling stopped at the end of the 1650-meter shot of nylon. The mooring winch leader was hooked into the sling link between the 1650 and 200-meter shot of nylon and made fast to the deck cleats. The mooring load was then transferred from the capstan to the mooring winch.

The recovery continued with the 200nylon/100m 3/8" wire rope special termination and the three shots of 500 meters of 3 /8" wire rope. The two SBE-39s clamped on the 3/8" wire rope were removed.

The procedure for recovering the instruments went as follows: with A-frame boomed out over the stern, the winch hauled in the wire. The first instrument was stopped about 2 feet above the deck and the A-frame was moved in. Two stopper lines were hooked into the sling link and made fast to the deck cleats. The winch payed out slowly in order to lower the instrument to the deck. The instrument was disconnected from the hardware and moved to a staging area for pictures.

The wire rope from the winch was then shackled to the load. The winch took up the slack and the stopper lines were eased off and then cleared. The A-frame was boomed out and hauling continued until the next instrument.

The above procedure was continued throughout the recovery operation until the VMCM current meter at 45 meters was recovered. Once the VMCM was recovered, a shackle and 5/8" pear link was attached to a link on the 3/4" chain. A slip line was used to set the buoy and remaining 40 meters of instruments adrift.

On October 26, the ship's rescue boat was deployed in the vicinity of the Stratus 7 buoy. The boat was used to observe the performance of the Boyle surface heat flux drifter buoy. Since the boat was going to be near the buoy, the crew was sent with the recovery sling and a 30-meter polypropylene line to attach to the buoy's lifting bale. This saved a second boat trip during the mooring recovery.

Once the buoy was set adrift from the stern recovery operation, The *Ron Brown* slowly approached buoy, keeping it along the port side of the ship. While the ship was maneuvering, the port crane was positioned above the recovery area on the port side. A grapple hook was thrown to retrieve the polypropylene line and recovery sling. The line was hauled back to the ship with the port side crane standing by. The sling was hooked into the block of the crane. The crane lifted the buoy from the water and swung inboard so the buoy would rest on the side of the ship. The tugger lines were attached to bails on the buoy. The buoy was hoisted up and then swung inboard while the tuggers kept tension on buoy to keep from swinging.

Once the buoy was on deck aircraft straps were used to secure the buoy. A stopper line was used to stop off on the 0.37 m shot of 3/4" chain between the first and second instruments. Tugger lines were removed from the buoy. The shackle was disconnected from the universal plate on the bottom of the buoy.

The large port side crane was disconnected from the buoy and stowed. The smaller Hiab crane on the main deck set up above the final instrument recovery area. The forward air tugger was fitted with a chain hook to aid in the recovery.

A 6-foot lift all sling was placed through the sling link at the top of the first instrument and hooked in the crane's hook. The crane took the load, and the stopper line was eased off and cleared. The crane hoisted the first two instruments and the tugger line with chain hook line was attached a section of chain and pulled tight. A safety stopper was attached to the link below the instruments hanging from the crane. Once the tugger had the load, the crane lowered the instruments to the deck. The instruments were disconnected and the crane was repositioned over the load. The sling was placed through the sling at the top of the remaining instrument array hooked into the crane. The crane took the load and the tugger and safety stopper lines were eased off and cleared. The crane lifted the next section of instruments and the above procedure was repeated to recover the remaining instruments. Figure 32 shows the recovered Stratus 7 mooring.

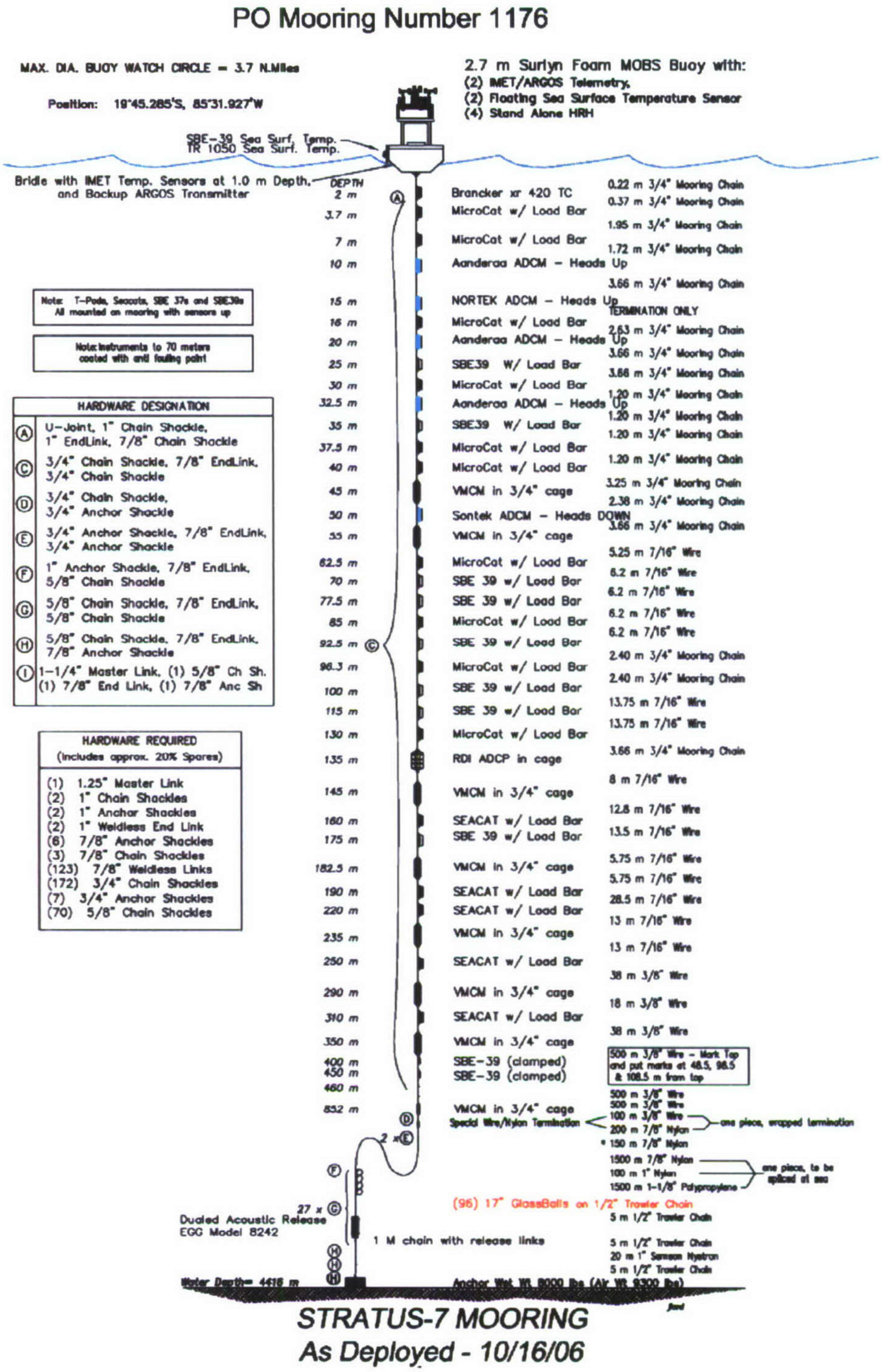

Figure 32: Stratus 7 Mooring Diagram Recovered

b. Stratus 7 Antifouling

Figure 33 below shows methods used for coating the buoy hull and instrumentation for the Stratus 7 deployment

Description	Coating	Color	Coats	Method
Buoy Hull	E-Prime SUNWAVE	Gray Blue White	1 2 3+	Roller Roller Roller
Floating SST SST Frame	SN-1 ZO	White White	2 2	Brush Spray
SBE 37s on hull bottom	ZO	White	2	Brush
Load Bars Trawl guards not treated	ZO & SN-1	WHITE	Brushed in area of sensors. Some bars had residual coatings	
**All instruments to 70 Meters	ZO & SN-1	White	2	Brush – applied only in area of sensors
Seacat/Microcat shields and conductivity cells	ZO	White	2	Brush
RDI ADCP heads (135 M) Residual trilux on heads	BIO-GREASE	Clr	1	Grease applied with gloves
VMCMs Props Sting ** ** stings on 45m & 55m only	 Epaint "p" - ZO	 Gray White	 2 2	 Spray Brush/Spray
ADCM/ADCP transducers Housings	Epaint – Bio Grease SN-1		1 2	Grease applied with gloves

Figure 33 The Microcats indicated were painted with ZO, all other instruments were coated with SN-1. Instruments closer to the surface had more area of the housing and load bar painted than those below 50 meters.

Antifouling Performance (Stratus 7)

- Traces of SUNWAVE paint were still visible on the foam section of the buoy hull, especially on the chine where additional coats of paint were applied. Gooseneck barnacles were attached to the foam from the waterline to the base of the buoy. The heaviest fouling on the foam was above the chine, at the water line. The density of barnacles appeared to be less than observed on the Stratus 5 buoy. There were a few mature barnacles, but most appeared to be young. The application of a tie coat, plus additional coats of SUNWAVE appears to have improved performance of the SUNWAVE product.
- In areas where paint was rubbed off the buoy foam prior deployment, barnacles were heavy and hard to remove.
- Fouling on the buoy base was moderate. Mature barnacles were mostly on areas with little or no coatings, such as the tie rods and hardware.
- Barnacles on the foam and buoy base were easily removed with a scraper.

- Overall fouling on instrumentation appeared heavier than on typical Stratus moorings. The instruments at 2m & 3.7m had less fouling than the previous years. Fouling below 3.7 meters was noticeably heavier. Instruments in the first 20 meters were heavily fouled.
- The coil on the XR420 C/T at 2 meters was only lightly fouled. The heads of all acoustic doppler current meters and profilers remained clear.
- Moderate fouling ended at 45 meters, and fouling below 70 meters was negligible. There were no barnacles below 180 meters. Barnacles appeared on deeper instruments than previous years.
- Most of the E-paint used on instruments had ablated almost completely. On some instruments below 20 meters, it appears to have been effective at reducing fouling near the instrument sensors.
- There is no significant fouling on Ti trawl guards or Stainless Steel cage parts. It does not appear worthwhile to paint these parts.
- Load bars get some fouling whether coated or not.
- Barnacle density is heaviest near neoprene strips, and at crevices such as where delrin clamps wrap around an instrument, or where T/C shield mount to pressure cases.
- Fouling on VMCM propellers was very light. VMCM cases at 45 and 55 meters had moderate fouling.

The Stratus 7 recovery revealed fishing line entanglement with some of the subsurface instruments. Historically this has been a problem due to fisherman targeting the large pelagic fish found underneath the buoy hull. Preventative measures are incorporated with subsurface instruments by protecting them with trawl guards that diminish line entanglement and instrument damaged. Fishing line was found on all of the following: SBE37-1330, SBE39-0276, SBE39-0476, VMCM-003, VMCM-004

c. Stratus 7 Subsurface Instrumentation Recovered

The primary data processing task, after recovering a buoy, is to duplicate all the instrument data to prevent possible loss. Further processing for inventory purposes and first-look troubleshooting is also done as time allows. For Stratus 7 recovery cruise, most of the instruments were processed through the inventory stage. Figure 34 lists the subsurface instruments recovered from Stratus 7

Instrument	Serial	Depth
SBE37SM L-04	1727	Bridle
SBE37SM L-15	1835	Bridle
TR-1050	12707	Float
SBE39	72	Float
XR 420	10514	2
VMCM	003	45
VMCM	004	55
VMCM	009	145

VMCM	013	182.5
VMCM	016	235
VMCM	061	290
VMCM	062	350
VMCM	083	852
SBE16	146	160
SBE16	991	190
SBE16	1873	220
SBE16	1875	250
SBE16	1881	310
SBE37	1325	3.7
SBE37	1326	7
SBE37	1328	16
SBE37	1329	30
SBE37	1330	37.5
SBE37	1906	40
SBE37	1908	62.5
SBE37	1909	85
SBE37	2012	96.3
SBE37	2015	130
SBE39	48	70
SBE39	49	77.5
SBE39	102	92.5
SBE39	103	100
SBE39	276	115
SBE39	284	175
SBE39	719	400
SBE39	720	450
SBE39	476	25
SBE39	477	35
Aanderaa	13	10
Aanderaa	78	20
Aanderaa	79	32.5
Nortek ADCP	2128	15
Sontek ADCM	D208	50
RDI	1281	135

Figure 34: Stratus 8 Subsurface Recovered

d. Stratus 7 Surface Instrumentation Recovered

The primary data processing task, after recovering a buoy, is to duplicate all the instrument data to prevent possible loss. Further processing for inventory purposes and first-look troubleshooting

is also done as time allows. For the Stratus 7 recovery, all of the instruments were processed through the inventory stage. Figure 35 lists the surface instruments recovered from Stratus 7.

Stratus 7 Serials/Heights

Module	Serial	Firmware Version	Height Cm
		System 1	
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	L-04	LOGR53 V2.70	
HRH	232	VOS HRH53 V3.2	223
BPR	207	VOS BPR53 V3.3 (Heise)	237.5
WND	222	VOS WND53 V3.5	273
PRC	205	VOS PRC53 V3.4	241
LWR	214	VOS LWR53 V3.5	283
SWR	219	VOS SWR53 V3.3	282
SST	1727		-151
PTT	18171	27919, 27920, 27921	
		System 2	
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	L-15	LOGR53 V2.70	
HRH	231	VOS HRH53 V3.2	223
BPR	217	VOS BPR53 V3.3 (Heise)	237
WND	215	VOS WND53 V3.5	271
PRC	208	VOS PRC53 V3.4	241
LWR	218	VOS LWR53 V3.5	283
SWR	212	VOS SWR53 V3.3	282
SST	1835		-151
PTT	12789	27916, 27917, 27918	
		Stand-Alone Module(s)	
Module	**Serial**	**Firmware Version**	**HeightCm**
HRH	216	VOSHRH53 V3.2	208
LASCAR	3	1hr Samples for 1.8 yrs	219
LASCAR	4	1hr Samples for 1.8 yrs	190

Figure 35: Stratus 7 surface recovered.

6. Meteorological Intercomparison

Between the Stratus 8 buoy launch at 18:27 on October 27 and the recovery of the Stratus 7 mooring, which began on October 29 at 10:57, we had an opportunity to compare the data from the surface instruments on the two buoys with data from shipboard instruments.

The Ron Brown has a complete set of meteorological instruments on board, which are logged on a central server and made available to the science party in real time as 1-minute "event files" subsampled from higher rate data on the server. During the cruise, shipboard data was aggregated and plotted continuously. We also collected buoy data in real time using an AlphaOmega Uplink receiver to monitor the Argos satellite messages, which contain hourly averages of data from the surface instruments on the buoys. These data sets are processed with a suite of Matlab routines that run continuously during our cruises.

After the Stratus 7 recovery, we combined the Stratus 8 Argos hourly data, the internally-recorded 1-minute data from the recovered buoy, and the 1-minute shipboard data for confirmation of sensor performance on both buoys. The shipboard values displayed here were filtered using a 10 minute boxcar average in Matlab, the Stratus 7 data is unfiltered, and the times in the Stratus 8 Argos averages are corrected to the center time by adding 30 minutes to the time word. Figure 36s through 40 are comparison plots.

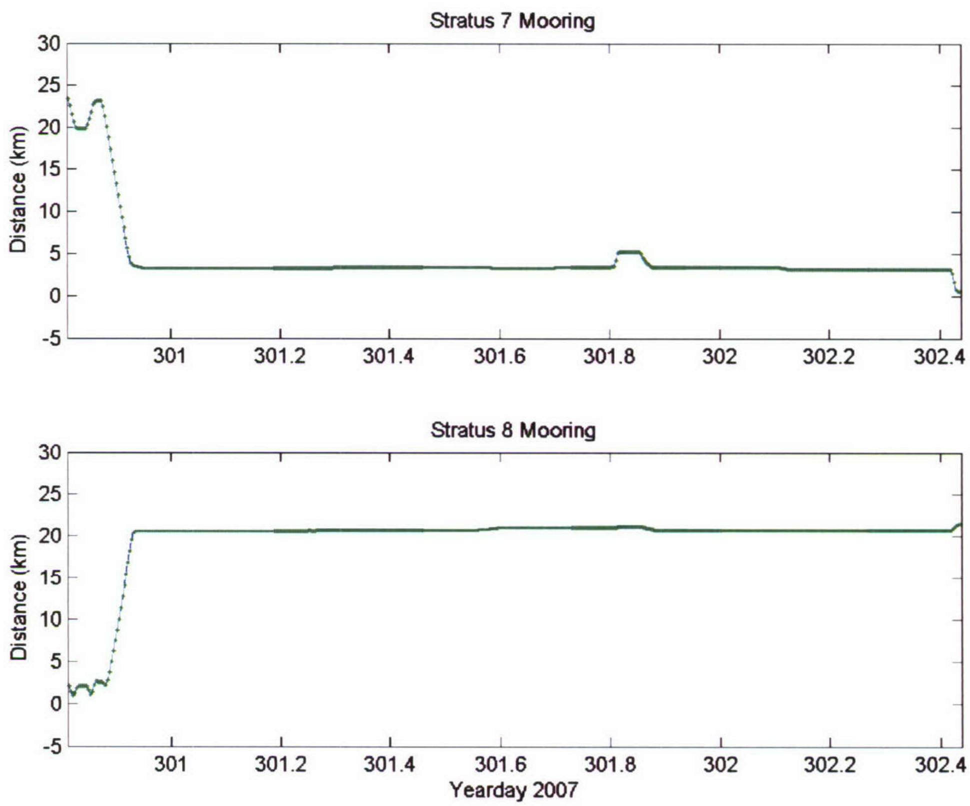

Figure 36: shows the distance between the ship and each buoy for the time period during which both buoys were in the water.

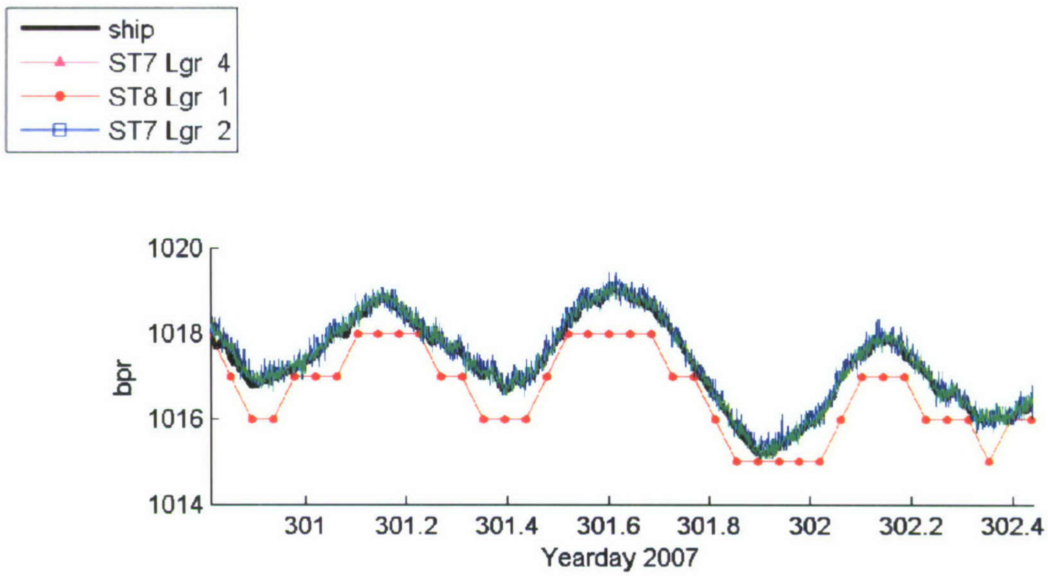

Figure 37: shows the comparison between barometer data. Stratus 7 data is plotted as blue and green solid lines, Stratus 8 as red circles and magenta triangles, and the shipboard data is a solid black line. The Argos data stream averages barometric pressure to integer values. The shipboard unit is adjusted for sensor height above sea level.

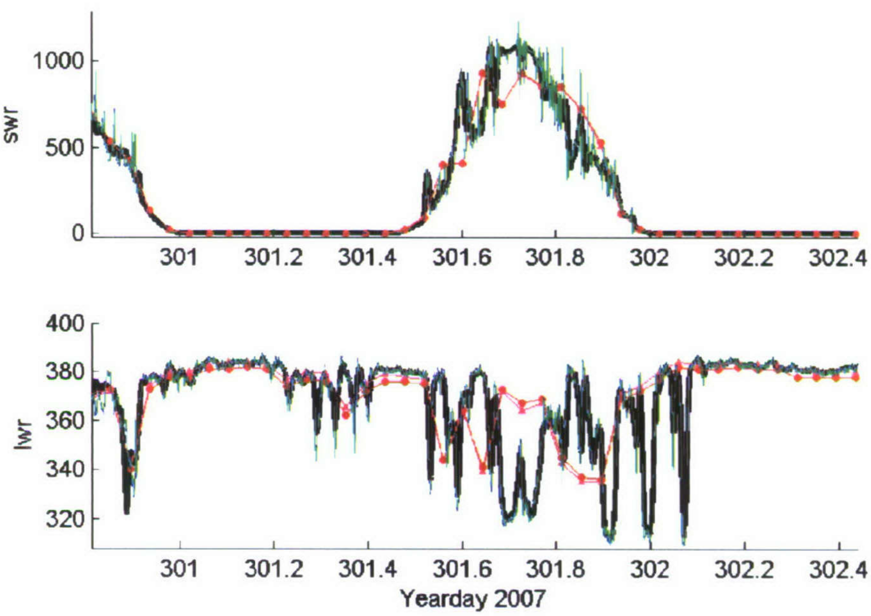

Figure 38: shows the solar radiation and longwave radiation sensors. A more complete comparison with sensors mounted on the 02 deck is provided elsewhere in this report.

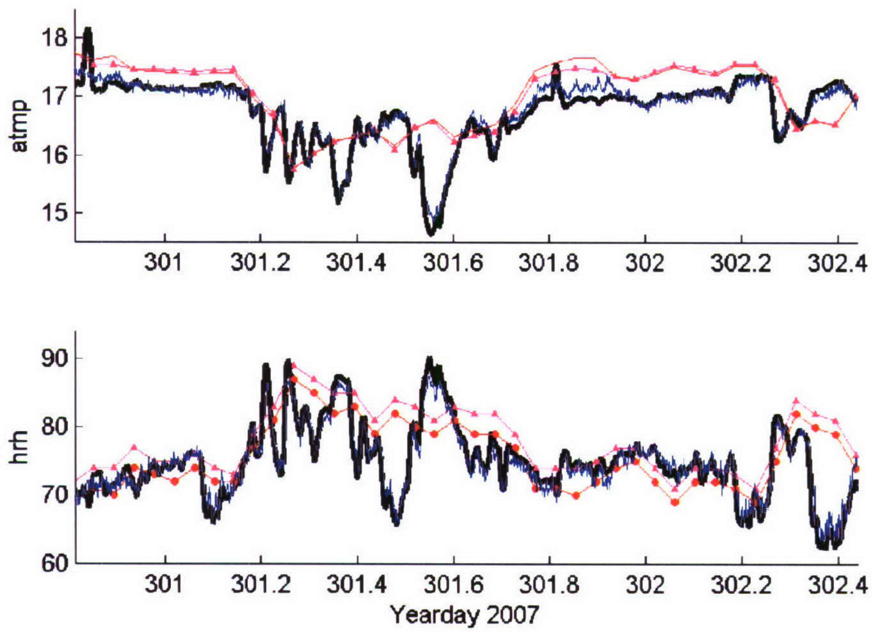

Figure 39: shows air temperature and relative humidity. Because the HRH sensor on logger 15 stopped before the cruise began, that instrument is not shown.

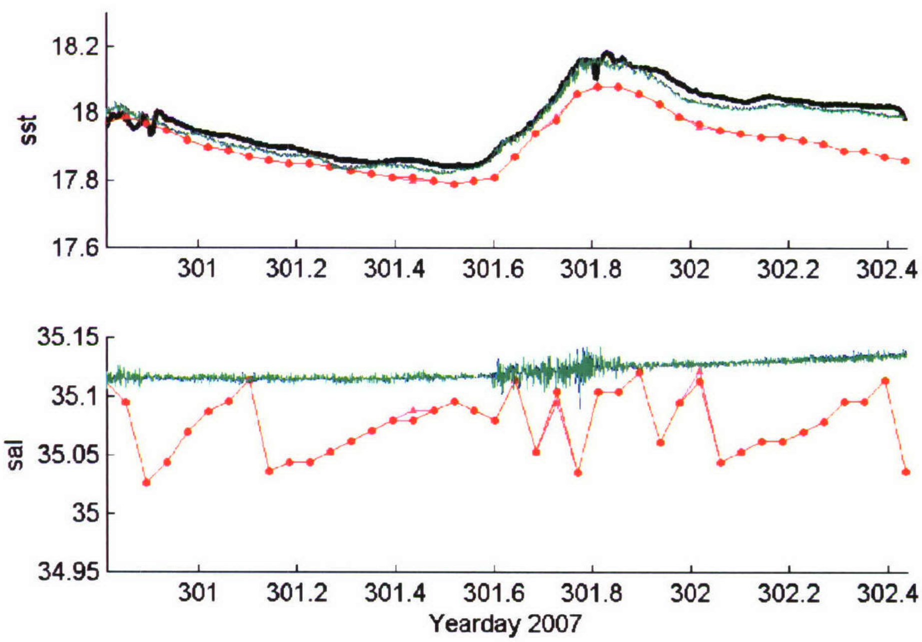

Figure 40: shows the comparison between shipboard thermosalinograph and buoy Seabird SBE 37s. The shipboard conductivity sensor malfunctioned during the transit to the Pacific, the salinity values it produced were not valid during the intercomparison period.

There was no rainfall during the buoy intercomparison, so rain gauge data is not shown.

7. Comparison of Radiometers

The values of downwelling longwave and shortwave radiation are important components of air-sea energy transfer. For almost two decades, efforts have been made to improve the accuracy with which both of these variables may be measured. With a nominal goal for accuracy of the ocean heat balance set at 10 Wm^{-2} over weekly to monthly timescales, individual components must be known to just a "few" Wm^2. Confidence in the instrument calibration facilities and procedures is key. In the case of the longwave radiation, some early confusion over the function of the measuring instrument (the pyrgeometer) has led to better understanding of how it works and the care with which it must be used. By comparison, the shortwave radiometer (the pyranometer) seems a straightforward instrument, and its performance has not been seriously questioned by the ocean-going community. But in fact, solar radiation can be the dominant component of the ocean heat budget, with midday peak values in excess of 1200 Wm^{-2} and daily averages around 250 Wm^{-2}, and we should question whether current pyranometer calibration procedures guarantee accuracy to our "few" Wm^{-2}.

On the forward 02 deck of the Brown in Stratus-8 we have assembled perhaps the largest number and variety of longwave (5) and short-wave (7) radiation instruments ever on a ship for inter-comparison. In particular, we aim to compare the performance of both longwave and shortwave instruments from the two manufacturers who dominate the market, Eppley (USA) and Kipp and Zonen (Holland). We also have a unique instrument, the SRN1, from Delta_T (UK) which purports to determine simultaneously both direct and diffuse components of the global shortwave radiation.

Figure 41 shows the distribution of these instruments around the deck and Figure 42 is close-up of each installation. Far right in figure A, we have a set of three mounted on a pole fixed to the starboard rail. From port to starboard they are an Eppley pyranometer (PSP), the SRN1, and an Eppley pyrgeometer (PIR). The two Eppleys are the standard radiation modules used on WHOI reference buoys. Later in the cruise, the SRN1 was moved to a separate pole 2.2m further aft, to test whether its dome had been influencing the PIR readings. On a pole fixed to the forward rail to starboard are four radiometers, 2 PSPs and 2 PIRs, which are part of the PSD meteorological installation on the Brown. Their performance has been carefully monitored over many cruises, and they are taken as reference for these inter-comparisons. Further to port on the same rail are a PSP/PIR pair, part of the ship's meteorological system (IMET). Forward on the roof of the container are three Kipp and Zonen (KZ) radiometers, from port to starboard a pyrgeometer (CG4), and two pyranometers (CM22 and CMP22). The difference in these two is that the CMP22 has a thermistor embedded in the body, which enables a small correction for sensitivity of the calibration constant to temperature. We did not make use of this feature.

Figure 41: Foredeck of RHB showing radiometer installations.

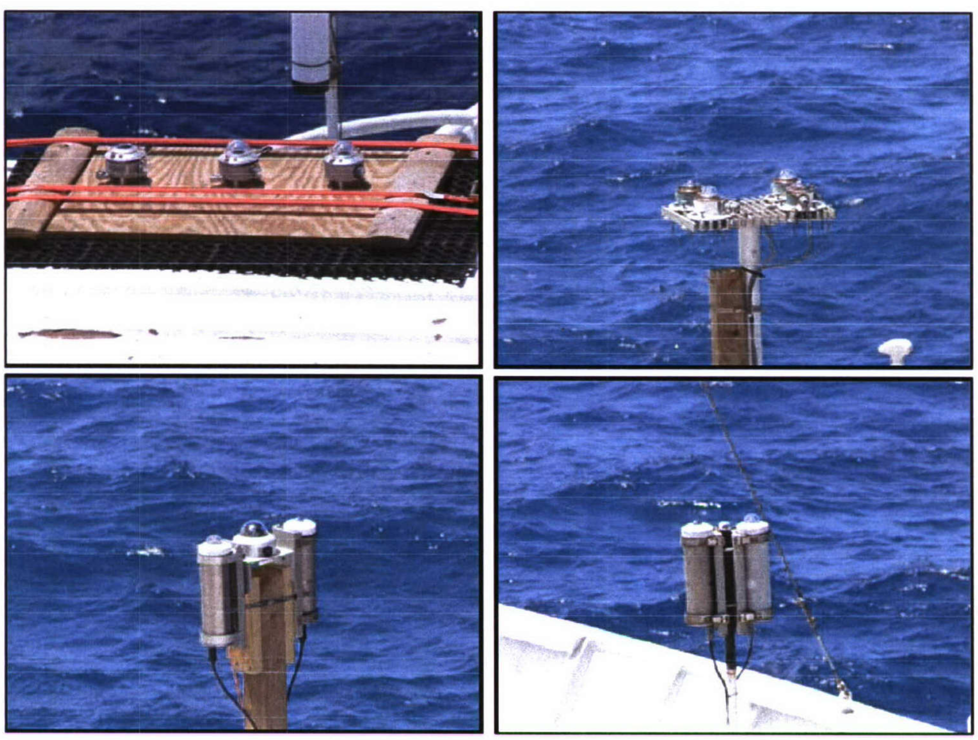

Figure 42: Detail of radiometer sites as described in text: clockwise from top left; Kipp and Zonen instruments; four PSD instruments; IMET PIR and PSP pair; WHOI PSP, SRN1 and PIR.

The instruments were leveled carefully while the ship was steaming through an area of remarkably flat sea soon after departure from Charleston, with very little ship movement.

The various sets of instruments were recorded on separate systems, all synchronized to GMT. Recording began on Day 284 (11 October) and continued (with breaks for territorial requirements) until Day 305 (1st November). For the comparison analysis, 1-minute averaged data-sets were needed because of the rapidly varying nature of radiation signals in a cloudy environment. In this respect, the Stratus cruises are not ideal for the observation of radiation, and the shortwave studies rely to some extent on data collected during the occasional clear patch of sky. At the same time, even under a complete cover of thin stratus, values of shortwave radiation in excess of 700 Wm^{-2} for extended periods are common, so the performance of pyranometers in a regime of diffuse radiation is important.

Long-wave radiometers
Pyrgeometers measure the downwelling thermal radiation by determining their own thermal energy balance. As well as the longwave energy entering through the dome and heating the thermopile, temperatures of the instruments dome and case are needed. The Eppley PIRs have embedded thermistors for this purpose, and the most important advance in pyregeometer use in recent years comes from recognition that an internal battery circuit, intended to simulate the contribution of the case temperature, seriously degrades the measurement. The pyrgeometer formula, which contains terms for the thermopile, case and case-dome temperature differences has also been refined. Kipp and Zonen have recently released the CG4 with a different construction – a rather flat dome which the manufacturers claim makes for easier deposition of the solar interference filter, and whose material and bonding to the case reduce their temperature difference and make the third term in the pyregeometer equation superfluous

As is to be expected, radiometers used in the USA are mostly Eppley, while KZ are more common in Europe. Our project is an opportunity to compare these instruments which differ in both construction and calibration method. The Eppley is normally calibrated in a black body cavity, while the KZ is calibrated "outdoors under a mainly clear sky during nighttime" against a similar instrument whose calibration is traceable to the World Radiometric Centre reference instruments.

From the 21 days of observation, we have selected for demonstration examples where conditions were relatively steady for long enough periods to provide meaningful averages. Figure 43 is an expanded trace of all the PIRs over a 5-hour period during a night late in the cruise, the dips being caused by variability of the cloud cover. The instruments track one another extremely well, within an envelope of about 5 Wm^{-2}, which is a remarkable result. The green and mauve traces are the two PSD instruments which track within about 1 Wm^{-2} of one another. Only a few years ago such agreement would have been unthinkable. The KZ instrument agrees well with the Eppleys under these conditions. To put numbers to this agreement, on each day between 290 and 303 three or four fairly steady periods of at least 100 minutes were selected, and for each pyrgeometer the average difference against the reference PSD1 were calculated. They are, for nighttime:

PSD2	CG4	WHOI	IMET
0.93 Wm^{-2}	-0.31 Wm^{-2}	2.07 Wm^{-2}	-1.80 Wm^{-2} ,

and for daytime when cloudy:

1.06 Wm^{-2}	-0.03 Wm^{-2}	2.53 Wm^{-2}	-0.89 Wm^{-2}

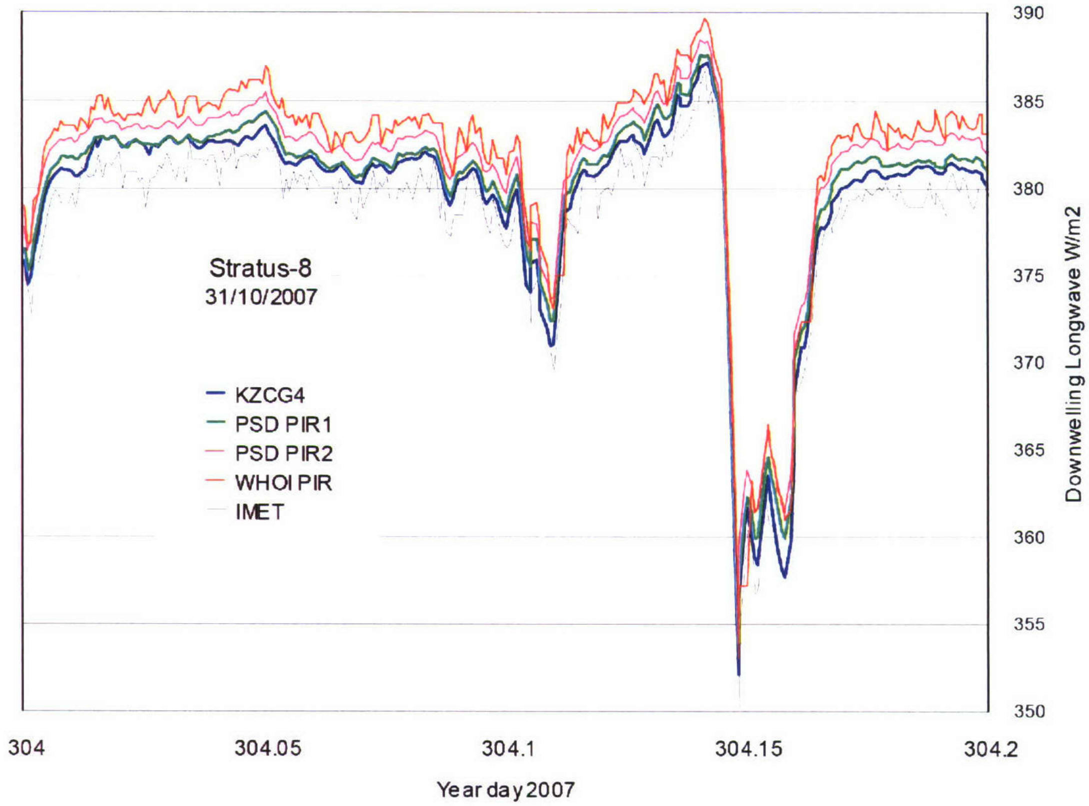

Figure 43: Expanded trace of all the PIRs over a 5-hour period during a night late in the cruise, the dips being caused by variability of the cloud cover

On several days there is an indication in the time series of an increase in the values measured by the WHOI PIR relative to the others. This tends to be borne out by the above average differences. This may have been due to its proximity to the dome of the SPN1, so on day 302 the SPN1 was moved about 2.2m further aft. On day 303 this phenomenon was noticed again, so it's obviously due to some other influence, which will be investigated further.

Figure 44 shows the longwave trace for a situation which occurred on a few days of this mostly cloudy cruise. The solar trace indicates clouds for much of the day, with a clear patch around midday. It is evident that the relative measurements between instruments changes at these lower values of radiation. The spread across the Eppley instruments is still less than 5 Wm^{-2}, but their relative position has changed. However the KZ pyrgeometer is now significantly lower than the rest, although still within the accuracy claimed for these instruments. It's worth noting that this is probably the level of radiation at which the sensitivity of the KZ was determined, during an outdoor calibration on a clear night in Holland.

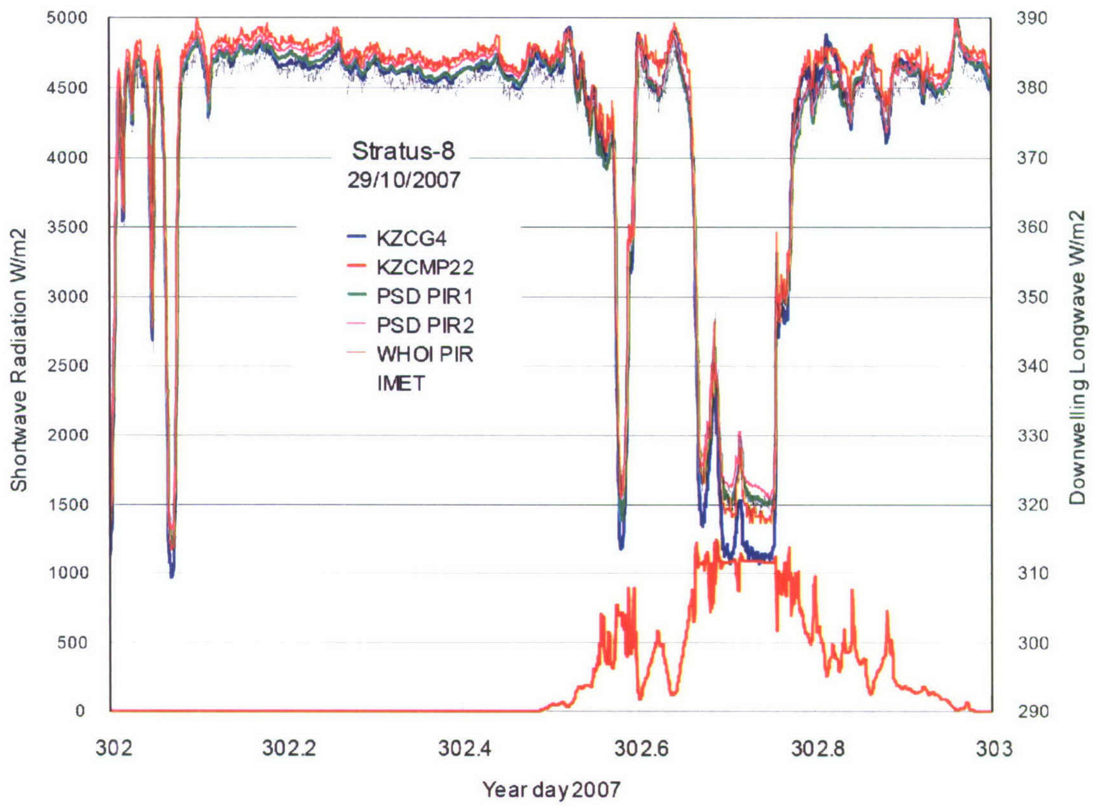

Figure 44: shows the longwave trace for a situation which occurred on a few days of this mostly cloudy cruise.

It is of interest to calculate the change in net longwave radiation caused by this sudden clearing of cloud at this point. The sea temperature was about 15.8°C so before the clearing net longwave was a loss to the ocean of 10 Wm^{-2}. For 2 hours on this day it changed to a loss of 75 Wm^{-2}. The atmosphere was rather dry at this time – the radiative sky temperature was about 1°C.

In summary, we feel that the difficulties which have affected the measurement of the downwelling component of longwave radiation in the past are largely resolved, and either the Eppley or Kipp and Zonen pyrgeometers, with proper calibration and care, can make reliable observations within a few Wm^{-2}.

Shortwave radiation

As noted above, cloudy conditions make it difficult to view easily the differing response of shortwave radiometers. Even one clear day would enable us to plot the signal from a number of pyranometers over the diurnal cycle, and compare signals with each other and with a clear-sky model. However, we have several days when there are short periods of clear sky. Figure 45 shows one such day when the sky overhead cleared for about half an hour and the differing sensitivity of six pyranometers is obvious. The larger signal on either side of the clear patch is a good example of the diffuse component enhancing the direct solar beam. The SPN1 gave an even larger signal than the KZ CM22, but is not included in this plot, because it does not profess to be a top class instrument like the Eppleys or Kipp and Zonen.

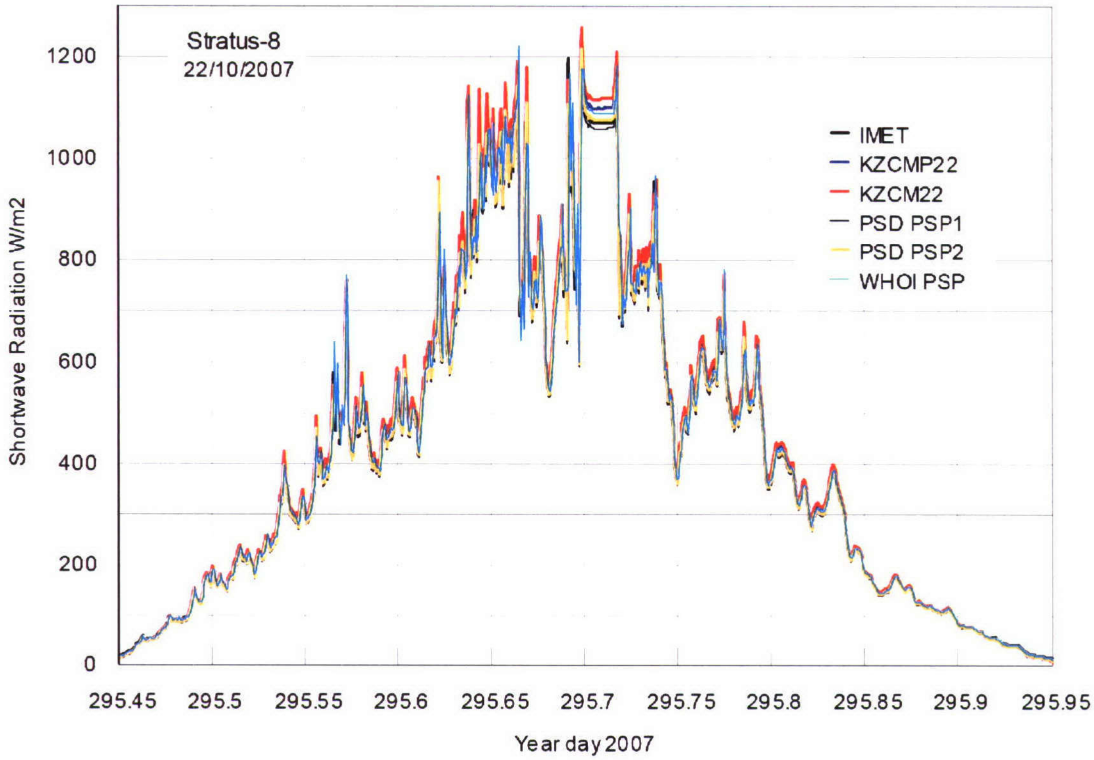

Figure 45: shows one such day when the sky overhead cleared for about half an hour and the differing sensitivity of six pyranometers is obvious.

The spread of measurements in this clear patch is around 70 Wm^{-2} or 6% which is greater than desired. More significant is that the 4 PIRs and 2 KZs fall into separate groups, suggesting that the calibration procedures and/or reference standards used by the two manufacturers are different. That this should be so, to the tune of 40 Wm^{-2} (a rough estimate of the mean difference between the two groups) is disturbing. The point is emphasized in Figure 46, a rare sunny day near the end of the cruise, which shows that the differences persist over the whole range of radiant intensity. The difference between morning and afternoon may be due to a slight lean of the ship relative to when the instruments were leveled at the beginning of the cruise. In this context, the sharp downward peaks (e.g., near day304.6) are useful in that they confirm the difference is not a sideways displacement caused by the several logging systems having lost time synchronization.

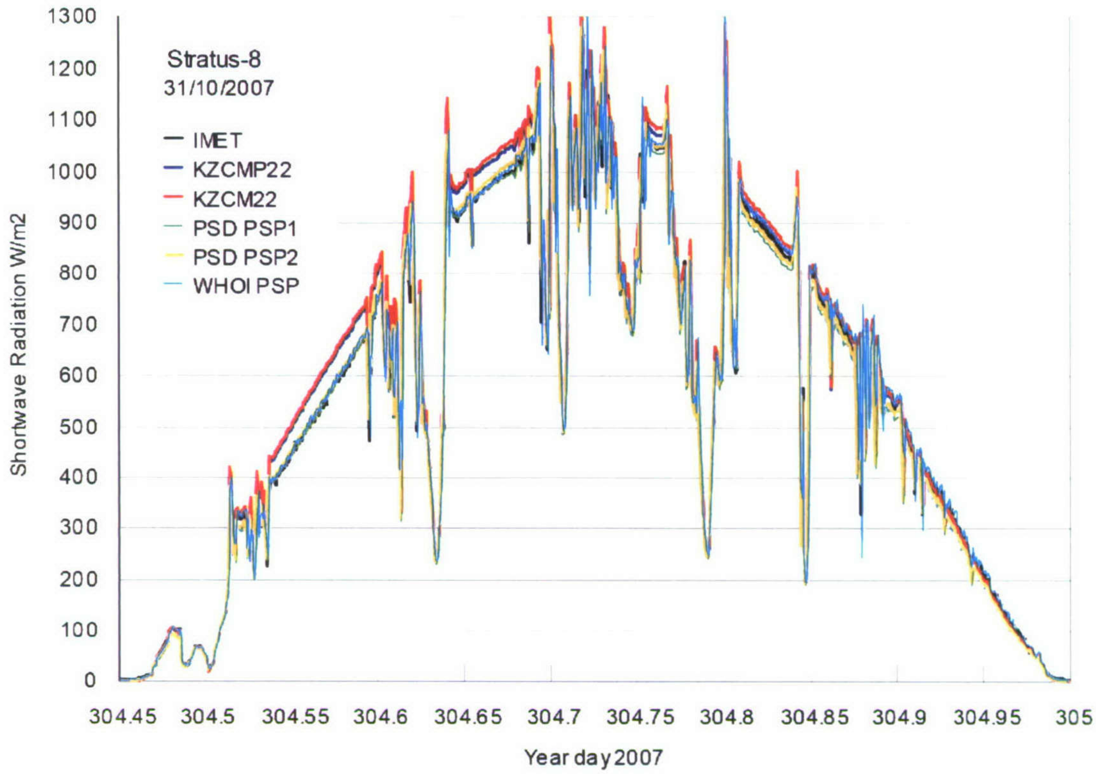

Figure 46: A rare sunny day near the end of the cruise, which shows that the differences persist over the whole range of radiant intensity.

Figure 47 is an attempt to quantify the differences between the pyranometers over the whole cruise and for a range of radiation levels. The points represent averages of the 1-minute time series for all 7 shortwave radiometers over periods of order ½-hour when conditions were fairly steady – i.e., no sharp peaks. The figure includes data from most days and therefore mostly represent cloudy conditions. They are plotted against the reference PSD-1, and apart from a few stray points are quite coherent. The lines are linear regressions, forced through zero, with slopes for example of 1.02 (WHOI PSP) and 1.06 (PSD KZ). The SPN1 has a slope of 1.09.

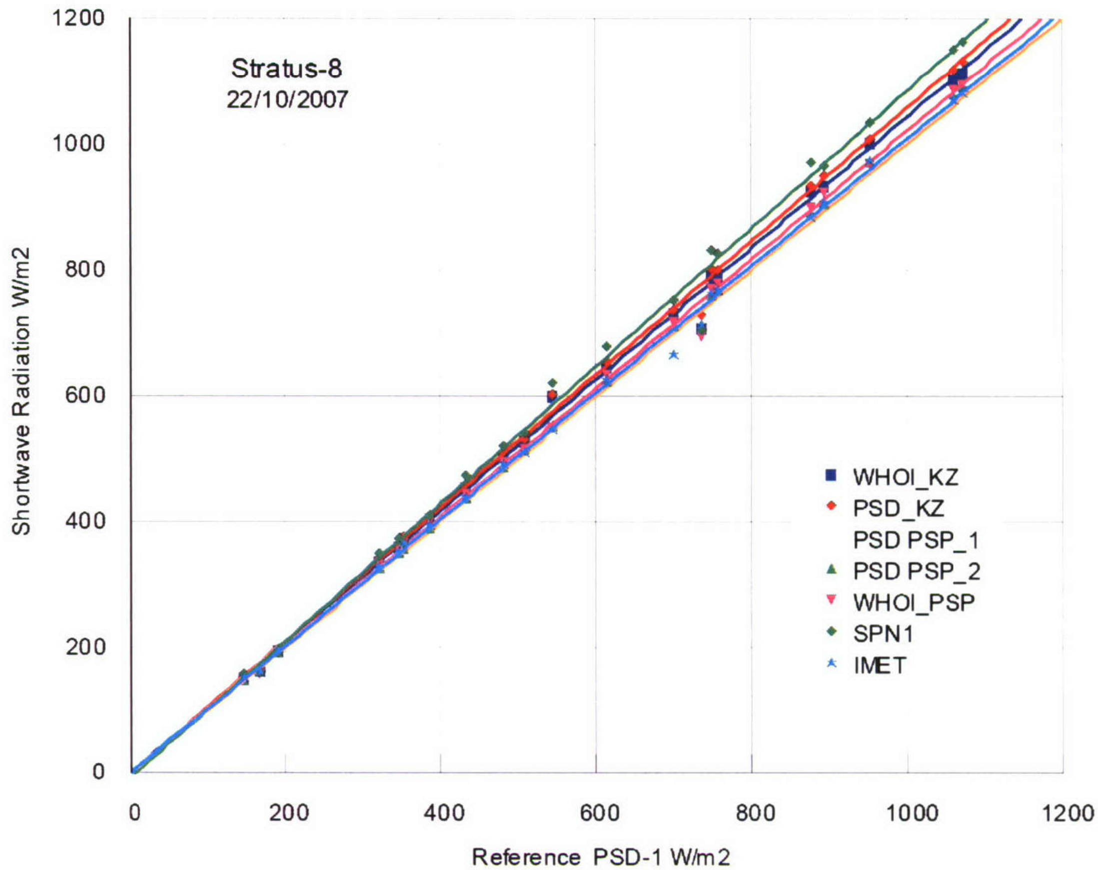

Figure 47: An attempt to quantify the differences between the pyranometers over the whole cruise and for a range of radiation levels

The situation is clearly unsatisfactory. Over the past few decades, the "Observation and Instruments Committee (or some such)" of WMO have made efforts to promote universal standards for the accuracy of observing networks, including radiation, and the establishment of a world radiation reference at Davos, Switzerland. There have been international radiometer intercomparisons of both pyranometers and pyrgeometers in various parts of the world (e.g., Oklahoma 1999). In their manuals for the CG4 and CM22, KZ describe in detail their calibration method and its traceability to a standard. But the comparison experiment described here indicates that more needs to be done. The air-sea interaction community urgently requires access to a radiometer calibration facility which is equipped to best international standards.

Tests of the SPN1

The SPN1 is a unique radiometer which is designed to measure both the direct and diffuse components of solar radiation. It is often useful to know the diffuse component of radiation, which is normally measured with a regular pyranometer fitted with either a shadow band or a tracking disk which casts a shadow on the dome and thermopile. The SPN1 achieves this with 7 separate thermopiles, and internal masks designed by computer to ensure that one thermopile

always sees the direct beam whatever the position of the sun relative to the instrument. But it must be level like all radiometers.

The output of the instrument is software generated, using the maximum (MAX) and minimum (MIN) signals from the seven sensors. The logic is explained in the user's manual. In summary, MAX represents the direct radiation plus half the diffuse, while MIN represents half the diffuse. Whence:

Diffuse = 2*MIN

Direct = MAX-MIN

Total = Direct + Diffuse = MAX+MIN

Calibration factors for the thermopiles are applied internally, and the software then applies corrections for sensor bias and spectral response. These subtleties in the physical design and software mean that its performance cannot be directly related to that of the other pyranometers. However, its calculated outputs can be compared with the measurements of the adjacent WHOI PSP.

Figure 48 shows the result from a day early in the cruise. After a few early clouds, it was clear most of the morning, then cloudy periods around midday and early afternoon. During the completely clear periods, the agreement between PSP and SPN1 was remarkably good. This conflicts with the result in Figure 47 where the SPN1 signal was about 7% higher than the WHOI PSP. There's no obvious explanation for this change.

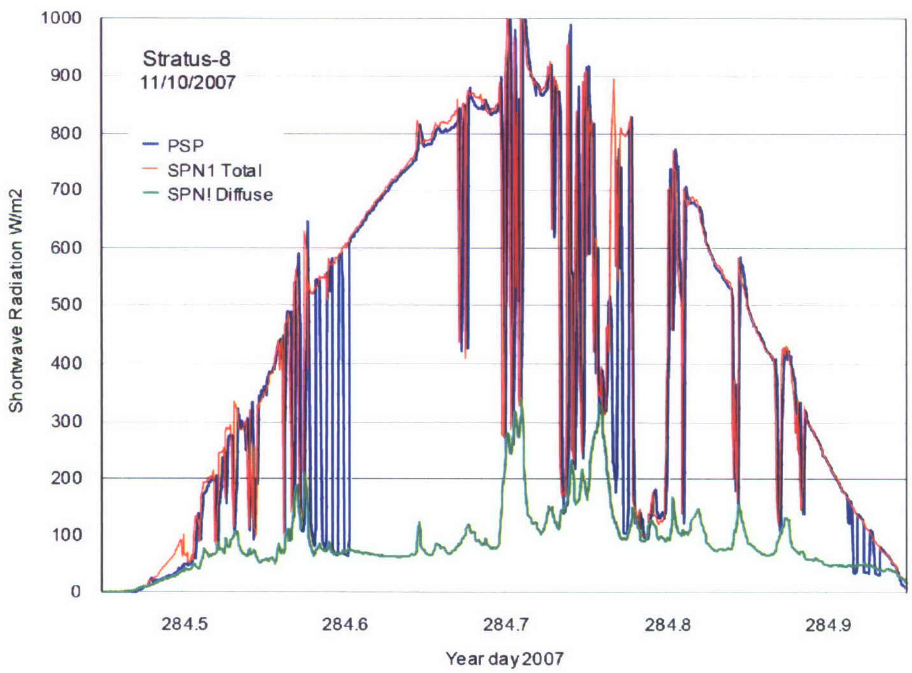

Figure 48: shows the result from a day early in the cruise.

At the beginning of the morning clear period, the PSP was shaded with a hand-held disc to exclude the direct beam, and thus measure only the diffuse component. The test involved 5 minutes shaded followed by 5 minutes clear, performed several times. When shaded, the PSP

output fell sharply (vertical blue lines). The agreement with the diffuse output from the SPN1 (green line) is impressive. Another shading test was performed after midday, and a third just before sunset. There were also a few periods when dark clouds covered the sun, and the naturally diffuse signal from the PSP agreed well with that from the SPN1 during this period.

Similar shading tests were performed during the rare clear sky periods later in the cruise, with equally good agreement. While not claimed to be a competitor for the highly developed PSP and CM22, the SPN1 is a useful device, and a unique way of obtaining a good estimate of the diffuse component of solar radiation. On this cruise the SPN1 demonstrated that, while the diffuse radiation may be small in clear skies, it can be larger than the direct component, and indeed is the *only* component when it is completely overcast.

Cloud photographs

Cloud forcing is an important aspect of exchange processes at the ocean surface. During off-line analysis of cruise data it is often useful to know the sky conditions at the time, particularly in respect of cloud cover and type. During Stratus-8, sky photographs were taken on a regular basis from Day 291 to Day 306. Using a wide-angle lens, the procedure was to photograph over starboard, aft, port and bow in order, with the horizon just visible at the bottom of the shot. This was not done at particular times, but as convenient 5-6 times a day or when there was a significant change in cloud conditions. The actual date and time (GMT) are stored with each picture. Figure 49 shows an example of sky photographs.

Each set of four photographs is stored as one page in a PowerPoint photo album. There are seven such albums with titles like Strat8_Clouds_n.ppt, where n=1 to 7, and each holds two days of photographs. The second page of each album is a readme.

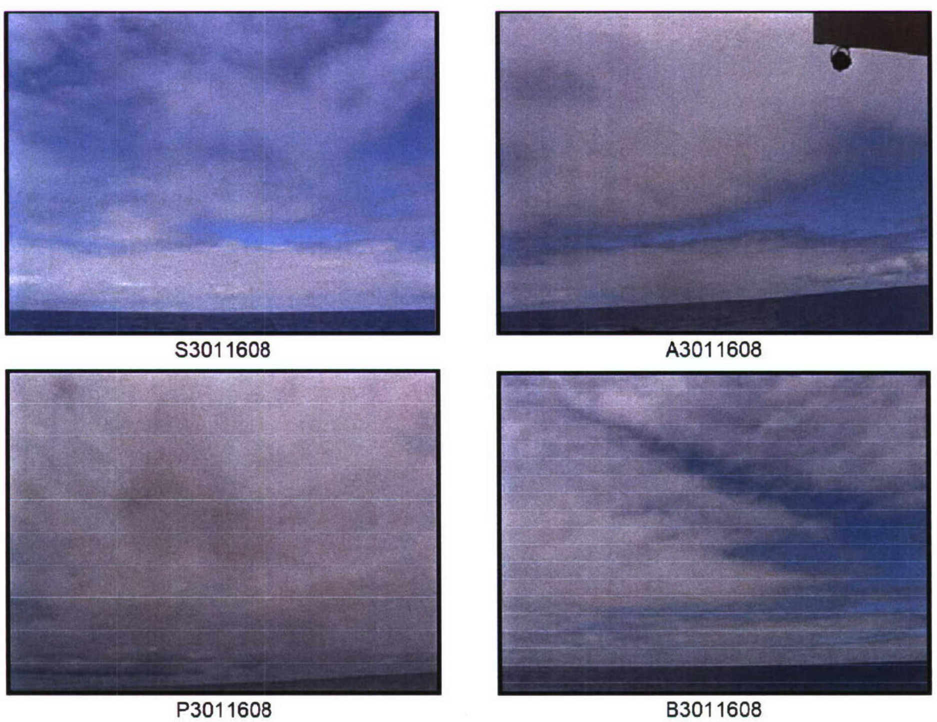

Figure 49: Example of one set of sky photographs, taken over Starboard, Aft, Port and Bow in sequence; day 301 at1608 GMT (about 1100 local)

8. Underway CTD

a. Overview

The UCTD is an underway system for acquiring conductivity and temperature profiles at ships speeds up to and exceeding 13 knots. See Figure 52 for profiling depths at different speeds. It is manufactured, packaged, and sold by *Oceanscience* in Oceanside, California. It was acquired and subsequently tested aboard the NOAA ship *Ronald H Brown* by the Upper Ocean Processes Group on the Stratus 2007 cruise in October of 2007.

Components

-Sea-Bird CTD Probe 10-400
-Tail Spool
-Tail Spool Re-winder
-Winch with Level Wind
-1400 Meters of 300 lbs Spectra Line
-Davit and Block
-Mounting Pedestal
-Power Supply
-UCTD software
-Bluetooth Software

Figure 50: Probe/ Tail Spool, Re-winder & Winch

The system is operated from the after portion of the stern deck (Figures 50 and 51 show components). A length of line equal to the desired cast depth is wound onto the CTD's tail spool. While the ship steams away from the drop site, the probe plunges vertically with a nearly constant drop rate independent of the ships speed.

Line is spooled automatically off the probe's tail while it drops through the water and line is manually payed out from the winch spool. The simultaneous payout of line from the probe's tail and winch effectively makes the line velocity through water zero, allowing freefall.

The CTD probe samples conductivity, temperature, and depth at a sampling rate of 16 Hz while descending vertically through the water column at ~4 meters per second. Data is stored internally in flash memory and downloaded wirelessly via Bluetooth to a host computer or PDA after recovery.

The latitude and longitude of individual casts is obtained by matching an internal time stamp in the data file header to an externally collected GPS file. Synchronization of instrument and GPS time is important. MATLAB scripts were used for processing.

Figure 51: Assembled UCTD

Depth	Speed	Turn-Around
200 Meter Tow-Yo	10 knots	10 Minutes
200 Meters	12 knots	30 minutes
800 Meters	4 knots	40 Minutes
1200 Meters	1 Knot	35 minutes

Figure 52: Typical UCTD Profiling Cycles

The range of the temperature sensor is 5 to 43 degrees Celsius, conductivities can be measured from 0 to 9 S/m, and the pressure range is 0 to 2000 m. The pressure housing is rated for a depth of 2000 meters although the operating depth is normally less than 1000 meters. Typical accuracies of the processed data are 0.005-0.02 degrees celsius for temperature, 0.002-0.005 S/m for conductivity, 1 dbar for pressure, and 0.02 -0.05 psu for salinity. Specifications are shown in Figure 53.

	Conductivity [S/m]	Temperature [°C]	Depth [dbar]	Salinity [psu]
Resolution	0.0005	0.002	0.5	0.005
Raw Data Accuracy	0.03	0.01 to 0.02	4	0.3
Processed Data Accuracy	0.002 to 0.005	0.004	1	0.02 to 0.05
Range	0 to 9	-5 to 43	0 to 2000	0 to 42

Figure 53: UCTD Specifications

During the STRATUS 2007 off of Ecuador, Peru, and Chile, over 300 casts were conducted. The probe was deployed every half hour and obtained a temperature and conductivity profile down to about 200 meters. See Figure 54 for a typical cast profile. Ship speed was 12.5 to 13 knots, allowing profiles to be obtained roughly every 6 to 7 nautical miles.

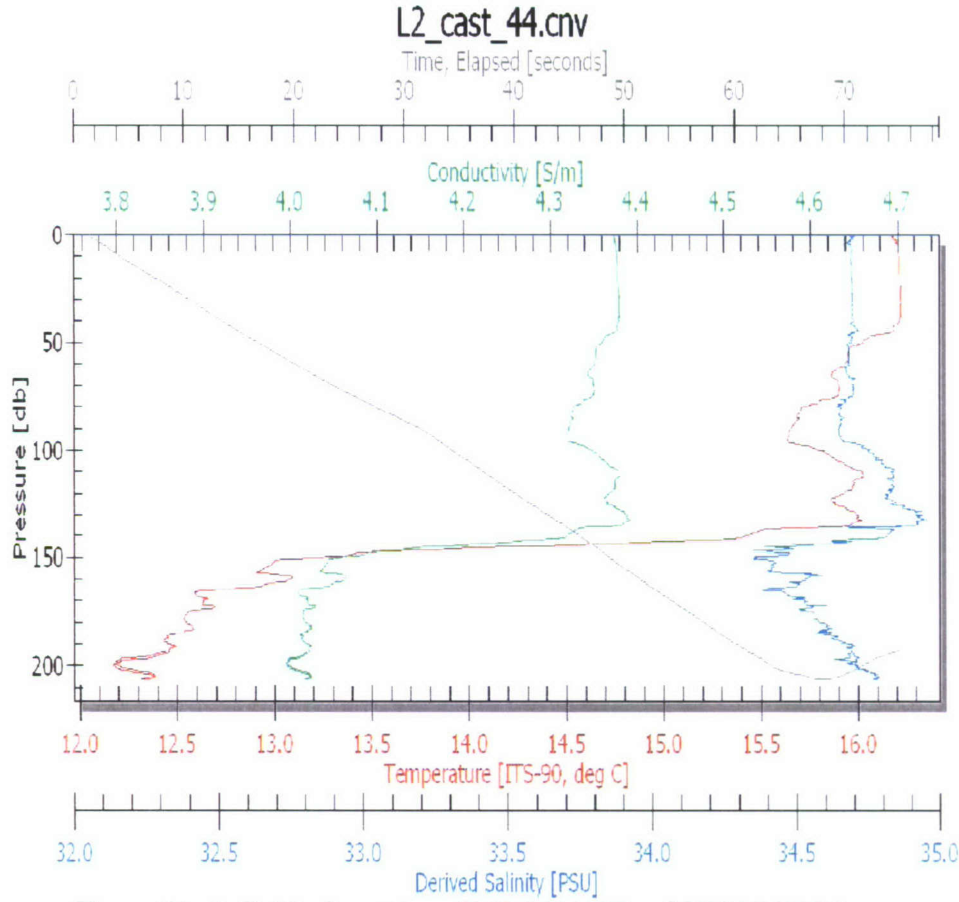

Figure 54: Individual cast from SHOA DART and WHOI ORS buoys.

With proper training and attentive use, the UCTD is an effective tool for acquiring conductivity and temperature profiles at ship transit speeds, optimizing valuable ship time. Also, the system consists of easily shipped and assembled components. The software and data processing were found to be unproblematic. Notably, the intense sampling scheme afforded by the UCTD provided a near real-time evaluation of conductivity and temperature profiles over great distances.

b. Summary of UCTD Operations on RHB between Charleston, SC and Rodman, Panama (Oct. 9-15, 2007)

Jochen Klinke, from *Oceanscience*, joined the ship in Charleston and departed the ship in Panama. While underway, intensive training was conducted with the UCTD. This included setup, deployment/recovery operations, data processing techniques, and trouble shooting. Dr Jochen's training was instrumental for the successful operation of the new Underway CTD system. The following provides some detail of the training while underway from Charleston to Panama.

The UCTD davit stand was set up just portside of the A frame as far aft as the 2 ft x 2 ft hole pattern in the deck of the RHB allowed. Most of the first day was spent mounting the individual components and performing a quick power up check to ensure the power supply, winch, levelwind, and rewinder would function properly on ship power. It was decided to run the power cable was straight across the aft deck between the mooring equipment and have it removed during mooring operations rather than guiding it alongside the rail. Still, it had to be extended by 25 ft to reach the nearest outlet in the dry bay. With the course of the RHB running through very shallow water for the first couple of days it was impossible to practice UCTD deployments, so we focused training on probe operations and maintenance as well as line splicing techniques instead. On the third day a few recoveries were performed with the dummy probe, keeping the probe at the surface at all times since the water depth was less than 20 m. Finally in deep water, full UCTD deployments commenced on the following day. We limited the depth of the initial tow-yos to ~200 m since the ship speed of 13.5 kt exceeded the operating specifications of the 10400 model. Due to excessive wear of line termination, the supplied tail pin was replaced with custom manufactured one. Also, the winch clutch was serviced to ensure proper free spooling. A combination of improperly machined parts and a ship speed over water of close to 14 kt lead to seizing of the winch on one occasion. While the material failure in the spool could not be repaired, it was possible restore the winch although only with a profile depth of less than 300 m at 12 kt. UCTD operations then commenced with free casts to 300 m at 11.6 kt and the day concluded with setting up the spare probe assembly. Communication with the probe via Bluetooth was established from both PC and Apple platforms, which allows relatively easy integration of the CTP profiles with the shipboard data. It will be necessary to replace the broken spool and service the winch after the Stratus 8 cruise to restore it to its full depth capacity, as well as supply new tail pins.

c. Preliminary Look at Underway CTD Observations Between 20°S, 75°W (SHOA DART buoy) and 20°S, 85°W (WHOI Ocean Reference Station)

While underway between the SHOA DART buoy and the WHOI IMET an Underway CTD (UCTD) was used to sample, dropping it roughly every half hour and obtaining temperature and conductivity down to about 200 m. Typical speed was 12.5 to 13 knots, so CT profiles were obtained roughly every 6 to 7 nm. The probe falls nearly vertically, then is rehauled on a tether line.

Figure 55 shows temperature versus depth along 20°S. The cooler coastal waters transition to water about 2°C warmer offshore. Figure 56 shows salinity as a function of depth and longitude. The complexity of water masses is indicated by fresh water intrusions seen below the surface

layer found in the upper 80 to 160 m, with that layer deepening going offshore. That surface layer is more evident in Figure 57, showing potential temperature and potential density. Individual CTD traces suggest water mass variability is associated in the upper layer with mesoscale structures. Concurrent shipboard ADCP data is being processed.

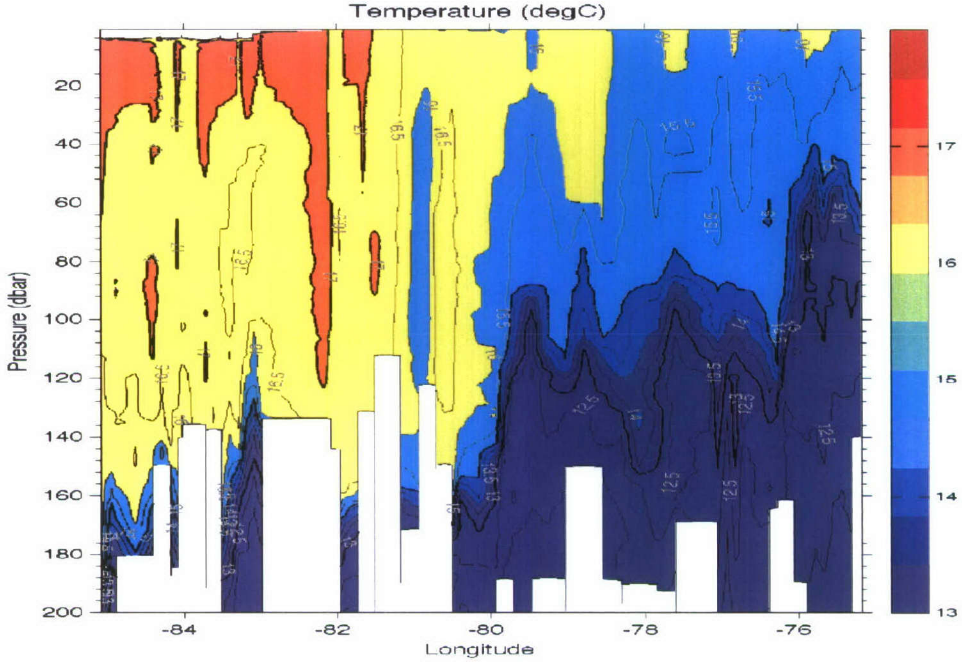

Figure 55: Temperature versus depth along 20°S between the SHOA DART and WHOI ORS buoys.

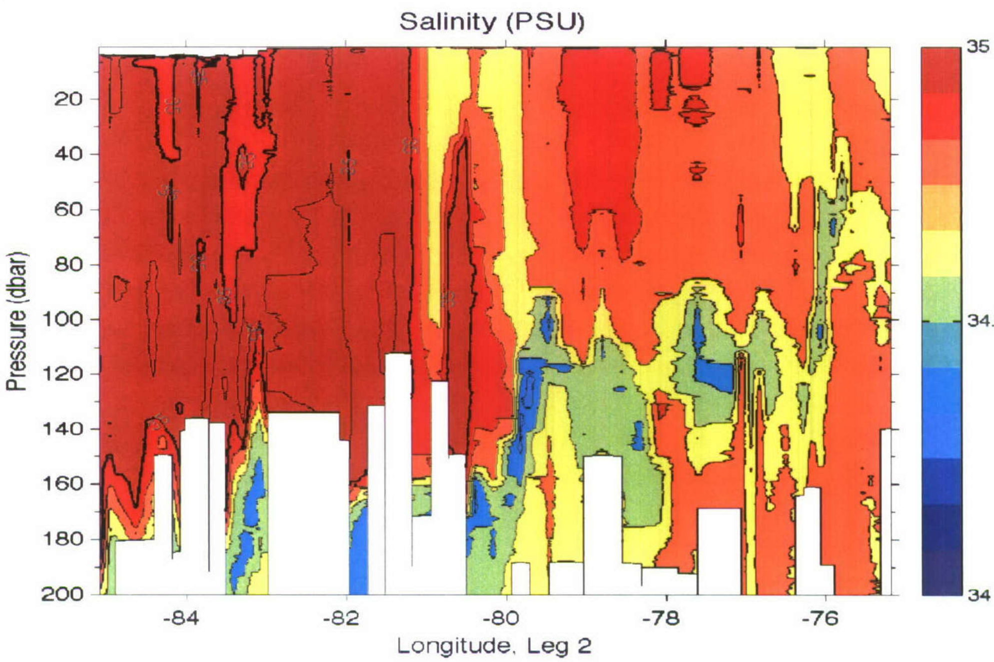

Figure 56: Salinity versus depth along 20°S between the SHOA DART and WHOI ORS buoys.

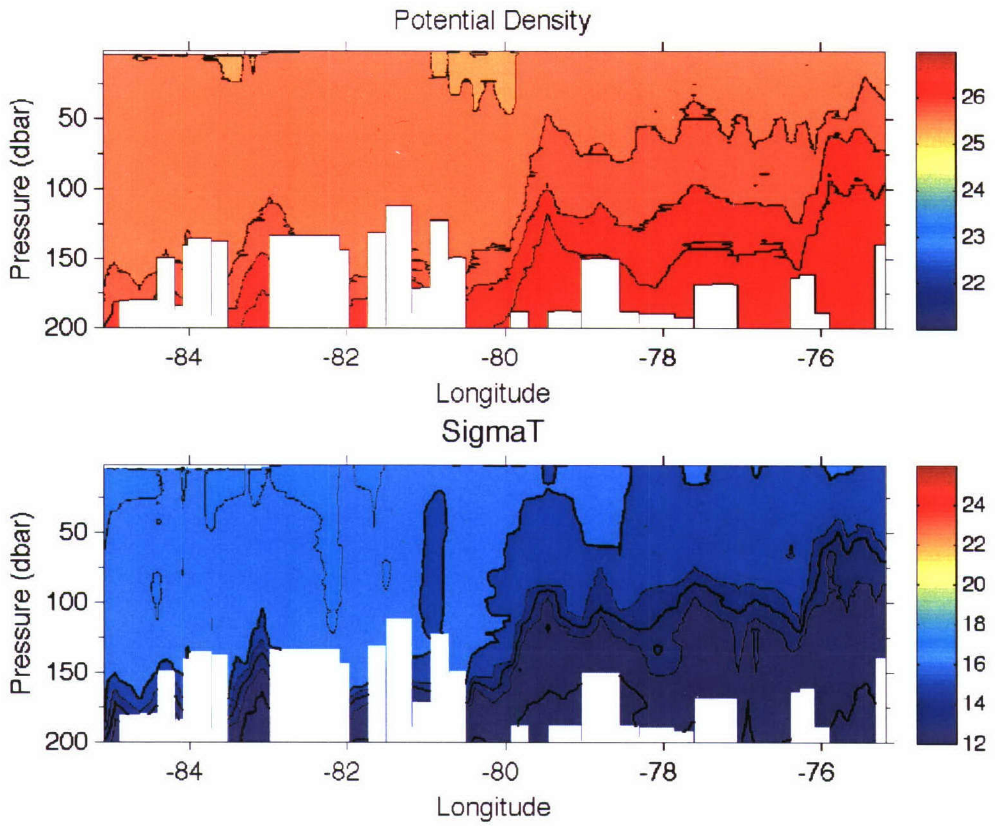

Figure 57: Potential density (upper) and potential temperature (lower) versus depth along 20°S between the SHOA DART and WHOI ORS buoys.

d. Hydrographic Conditions Off the Western Coasts of South America

The oceanographic conditions off the western coasts of South America during the October-November 2007 cruise of NOAA's R/V *Ronald H. Brown* to the Stratus Ocean Reference Station site at 20°S, 85°W is presented using an underway set of hydrographic measurements obtained alongshore off the coasts of Ecuador and Peru (Figure 58). Underway conductivity-temperature-depth (UCTD) measurements with high horizontal and vertical resolution were made along a transect from approximately 80 km (off Ecuador) to 240 km (off Peru) and extending from northern Ecuador (1° S) to northern Chile (19° S). Surface data of temperature, salinity, surface currents and fluorescence, as well as vertical sections of potential temperature, salinity, potential density (Figure 59), and currents are presented to illustrate the structure of the water column above 800 m depth.

Some features of interest found are described, and an attempt is made to interpret them associated with the regional climate setting.

Since April 2007, a La Niña-like event evolved in the western coasts of South America and strengthened in September and October 2007. The R/V *Ronald H. Brown* Cruise RB-07-09, Leg 1 was performed under this moderate to strong La Niña conditions. The data collected confirm

the presence of several spatial patterns described in the literature, more proper of winter season: (i) the relatively high salinity subsurface signature of the PCUC, (ii) the mesoscale variability of salinity structures displaying various local features more proper of winter season even 240 km offshore due to strong cold La Niña conditions as (i) the southern boundary of the equatorial warm and fresh waters was to the north of 4°S, likely because of surface mixing due to the stronger winds, and to the stronger equatorward Peru Coastal Current, (ii) the displacement of central Pacific water mass toward the coasts of Chimbote (9°S) to Pisco (13°S) and the westward advection of cold waters in southern Peru, (iii) the lower salinity lenses evidenced at ~100 m depth off southern Peru which, related to the core of SAW, seem to be relatively isolated and poorly mixed with surrounding waters, especially near the Nazca ridge, a topographic feature which could influence the vertical structure of eddies and the trapping of salinity cores.

The boundary layer meteorological data show the presence of southerly winds, a decrease in the air temperature, heat flux and the relative humidity and an increase in the pressure which characterizes current La Niña episode in the SEP.

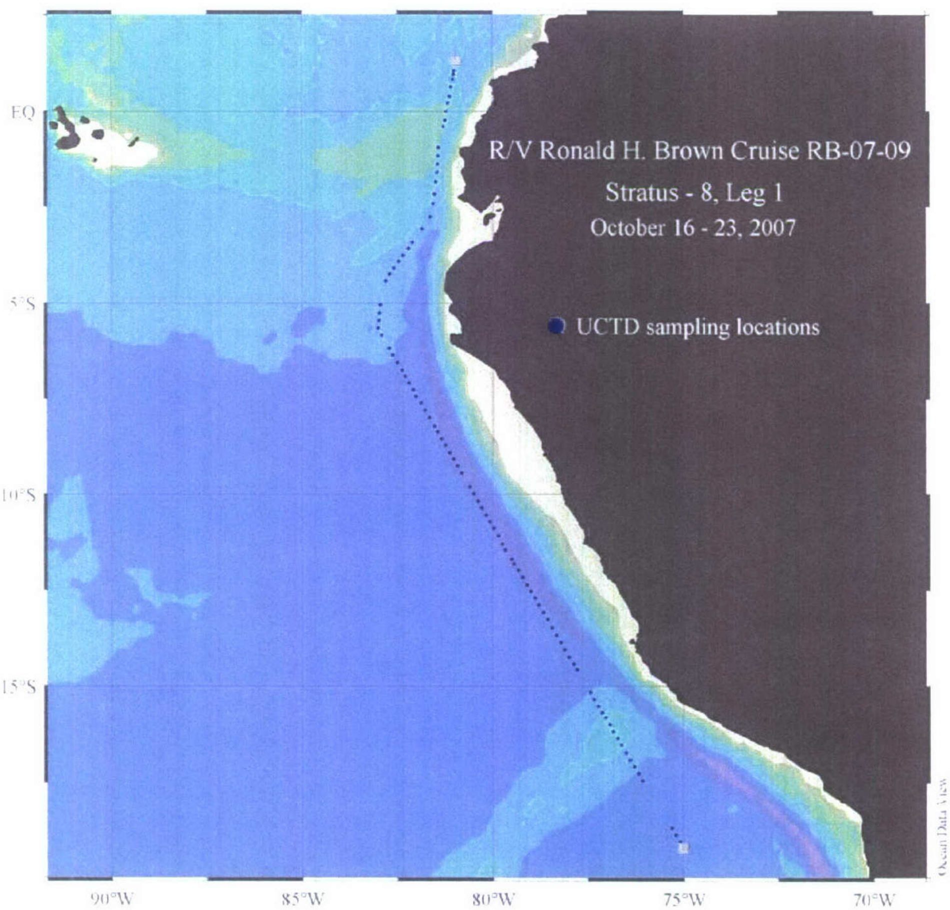

Figure 58: Ship track and Positions of the stations occupied by R/V *Ronald H. Brown* on Cruise RB-07-09, Leg 1 (Stratus Ocean Reference Station (ORS) project), October 16-23, 2007. UCTD sampling locations (black dots) are superimposed.

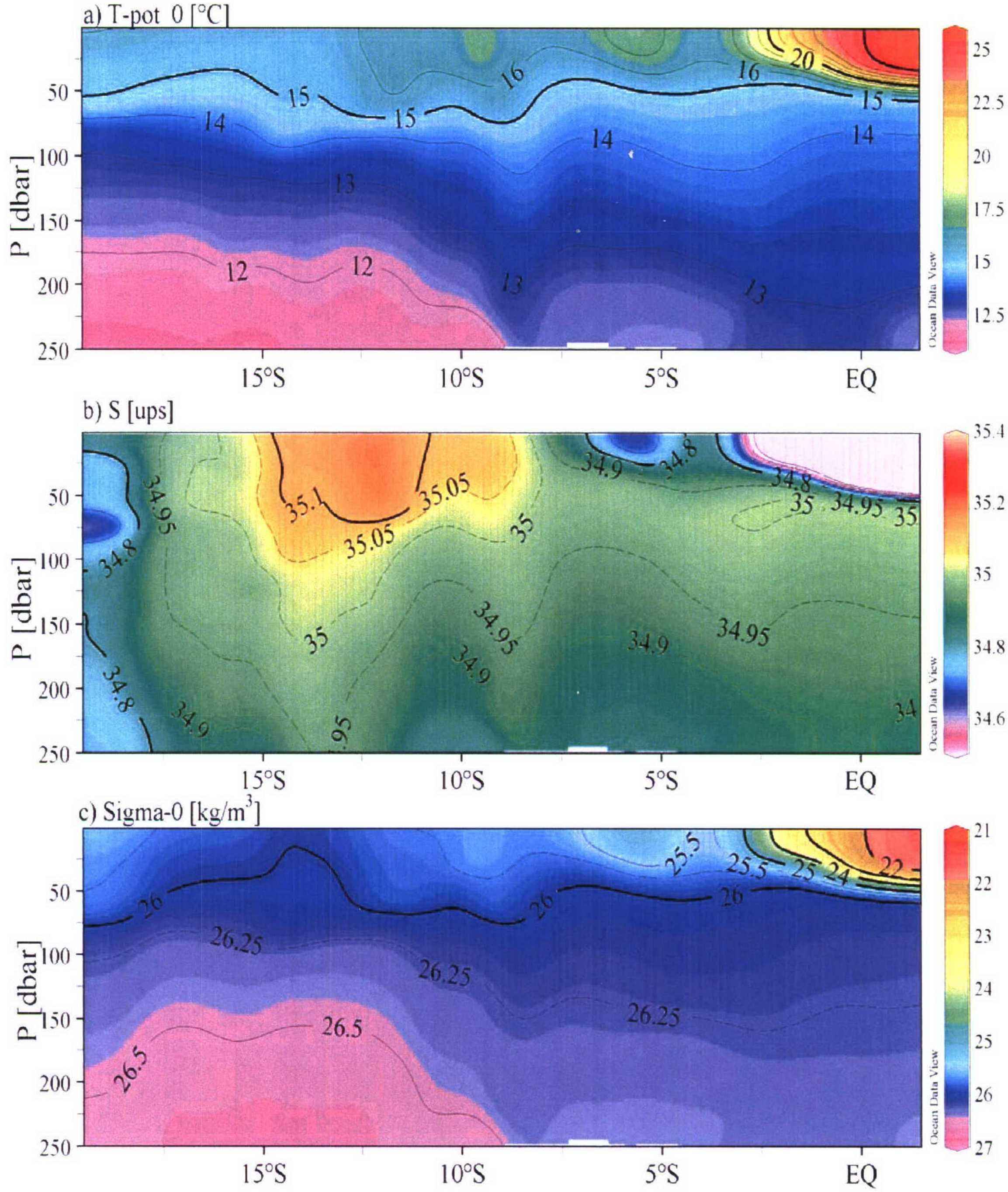

Figure 59: (a) Potential temperature [°C], (b) Salinity [psu] and, (c) Potential density [kg m^{-3}] in the upper 200 m composed from UCTD measurements along the ship track shown in Figure 58. UCTD sampling locations (grey dots) are superimposed.

9. Global Positioning System (GPS) Rawinsondes

Global positioning system (GPS) rawinsondes were regularly deployed on the Stratus 2007 cruise starting October 18 (yearday 292) 18:00 UTC until November 2 (yearday 306) 00 UTC. Figure 60 shows the track of the *Ron Brown* and the released rawinsondes. The top of each rawinsonde trajectory is marked with a circle. For the purpose of the soundings, the cruise is divided into 4 legs:

1. Ecuador-Peru coastal section
2. SHOA/DART station at approximately 75° W, 20° S
3. 20° S section from 75-85° W
4. WHOI station at approximately 85° W, 20° S.

For the moving legs, soundings were released every 6 hours, approximately at 0, 6, 12, and 18 UTC. For the stationary legs, in an attempt to better sample the diurnal cycle, soundings were released every 4 hours, approximately at 0, 4, 8, 12, 16, and 20 UTC.

Leg 1: Ecuador-Peru coastal section

Overview of the 1°-20° S coastal section

GPS radiosondes were deployed on the Stratus 2007 cruise starting October 18, 18:00 UTC, and at 0, 6, 12, 18 UTC thereafter until reaching station at the DART/SHOA buoy just before October 23, 0 UTC. During this time the ship steamed south along the coastline of Ecuador and Peru, from 1° to 20° S. Owing to the spatial homogeneity of the stratus cloud deck in this region, the soundings show small and gradual variations in vertical structure of temperature, humidity, and winds with time and latitude.

Figure 61 is a contoured latitude-pressure section composed of the 19 soundings between 1° and 20° S. The top panel shows potential temperature, the second shows specific humidity, the third shows zonal wind, and the bottom panel shows meridional wind. The ticks and at the top of each panel mark the times when the sondes were released, 4 times a day; the numbers mark the beginning of the yearday. (Yearday 292 is October 19).

There is a weak indication of descending plumes in the specific humidity (Figure 61, panel 2). The stratification in the free troposphere is considerably stronger at 18S than at 2S. That is to be expected—as the ship progressed farther to the south, the soundings were sampling the atmosphere farther away from convection. Early in the cruise, there was a lot of convection south of the usual seasonal position of the ITCZ.

A southeasterly jet is at 8° S, 700 hPa, with a northwesterly jet above the boundary layer and below 800 hPa at 16° S. These winds were not noticeably affected by the diurnal cycle. Winds in the free troposphere could be quite variable in time, so we don't know how representative these observations are in general. Models have a lot of trouble with simulating winds so close to the Andes, which might be expected to affect reanalyses.

Thermodynamic structure and relation to clouds

Figure 62 shows a typical sounding of cloudy conditions observed on the morning of October 19, 10:00 local time, located at 5.4W, 83S. At this latitude, patchy upper level clouds were observed, and there are tongues of high relative humidity (~50%) especially at 3 and 4.5 km altitude. These tongues of high relative humidity above the boundary layer were associated with plumes of moisture detrained from convection taking place unusually far south for this season. The

inversion is 8°, with an additional layer of stability above the cloud. Disturbed by convection, the stratus deck was not as uniform here as it would become as we travelled farther south. The cloud layer is about 75 m thick, centered at 600 m.

Figure 63 is an example from October 21, 2 local, of a sounding observed farther south, where the relative humidity above the boundary layer is considerably drier and the stratus clouds are more solid. This sounding of a thin (150 m) stratus cloud, which nevertheless covers a wide area, is characteristic of the soundings observed on this coastal section. The cloud base is at about 750 m and the top at 900 m, with a subsaturated layer below the inversion. The inversion strength is 10° C distributed over 925-1025 m height.

Slight thinning and clearing of the stratus cloud deck was observed in the afternoons. On October 22, a pocket of open-cellular convection (POC) was identified from a mid-day (14:25 UTC) visual radiance image from the NOAA-17 polar-orbiting satellite (Figure 65). The ship was under clear skies in the influence of the POC by early afternoon (13:00 local). For about 2 hours, clearing was observed on the ship (passing during this time through 75W, 19S), and vertically-oriented cumuliform clouds were observed to the west. A later satellite image showed that a much wider region became organized into open-cellular mesoscale structures. The sounding (Figure 65) from October 22 noon exhibits a decoupled boundary layer structure, with relative humidity below saturation. Two maxima in relative humidity (minima in dew point depression) are seen at 500 and 800 m height, indicating a poorly mixed scattered-cloud layer in the upper half of the marine atmospheric boundary layer. The thermodynamics are under the influence of nearby decoupled boundary layer convection, likely cumulus rising into stratocumulus. The afternoon of October 22 the ceilometer observed cloud base as low as 550 m.

On October 23, 12:12 local, a rawinsonde was launched at 74.8W, 19.6S (Figure 66). The temperature and relative humidity show that the free troposphere was very dry. The inversion was 10°C, with additional 5° stability in the 100 m layer above the inversion. The water vapor was near saturation in a very thin layer at the boundary layer top. Clearing was observed the afternoon of October 23.

Leg 2: SHOA/DART buoy station

On October 22 at 20:00 UTC the ship reached the SHOA/DART buoy location. For the two days of October 23-24 (296-297) soundings were made every 4 hours. Two full days of sampling is marginally enough to sample the diurnal cycle. The ship left the SHOA/DART buoy location at yearday 297.5, but had only traveled slightly west of 77°W by the start of day 298.

Figure S8 shows a time-vs.-pressure plot of potential temperature, specific humidity, and wind components for year days 296-297. The contours have been chosen so that the diurnal cycle in the marine boundary layer is evident. Even during the two days, cycles are evident in all four variables. There is a minimum in potential temperature of 0.5-1.0°C at 7:00 local (12 UTC). This coincides with a minimum in specific humidity. The full cycle of specific humidity is about 0.5 g kg^{-1}. Also at 7:00 local, an easterly zonal wind jet at about 975 hPa reaches its maximum speed of about 5 m s^{-1}. Meridional wind is weakly positive at this time, but reaches a maximum of 5 m s^{-1} at 19 local. The diurnal cycle of wind appears indistinguishable from uniform below 850 hPa.

There is a warming trend of 0.5°C over the two days. The boundary layer height also tends to rise, especially throughout day 297.

Leg 3: 20°S transect

The ship traversed westward from 75 to 85°W along 20°S on days 297-299. This transect is interesting because it shows the evolution of the boundary layer from the coastal region to the open ocean, nearer the climatological center of the southeastern subtropical Pacific high. The transect was repeated in most of the previous stratus cruises since EPIC 2001. We plan to compare similarities and differences among the cruises along their 20° S legs.

On Stratus 2007 the temperature rose about 2°C from 75 to 85°W along 20°S. Figure 67 shows zonal-vertical sections of the boundary layer in this region. The boundary layer depth was observed to rise remarkably from 1.1 km to 1.6 km over this 10° of longitude. Half of the rise in boundary layer height is seen west of 83° W, where the boundary layer is vertically decoupled—marked by the horizontal orientation of boundary layer isentropes in the potential temperature section. When decoupled, a conditionally stable layer develops between cloud base and the surface mixed layer. Shallow cumulus clouds were observed in this conditionally stable layer. The cumulus clouds rose into the stratocumulus layer above. The stratocumulus cloud layer became broken and clear skies were observed overhead (with cumulus rising into stratocumulus on the horizon) nearing 85° W.

The second panel of Figure 68 shows the specific humidity, which increases slightly to the west. The yellow dots on the specific humidity section show the height of the cloud base deduced from the lidar ceilometer aboard the ship. The cloud base deepens at 81°W, and using the relative humidity gradient or potential temperature inversion as an indicator of cloud top, the clouds also thin by about 50% at 81°W. Intermittent shallow clouds below the stratocumulus base are first detected in the 10-minte averages of ceilometer cloud base at 81.75° W. This signature of cumulus rising into stratocumulus is observed west of 82°W and at the WHOI Stratus buoy station.

Zonal velocity is steadily easterly everywhere in the 20°S section, from the surface to 3 km. Meridional velocity is southerly (about 5 m s^{-1}) throughout the boundary layer, and more weakly southerly above the boundary layer east of 79°W. At 79°W there is a transition above the boundary layer, and the winds are ~5 m s^{-1} northerly above the boundary layer west of 79°W, with strong vertical wind shear at the inversion.

Figures 69 and 70 show individual soundings released on October 25 at 00:05 and 18:03 UTC, respectively, that are incorporated in Figure 68. The clouds in the two soundings are quite different, reflecting both the westward transit of the ship from 77.4° W to 81.5°W, and the diurnal cycle on October 25. (At 75°W, local time is UTC minus 5 hours; at 85°W local time is UTC minus 5 hours and 40 minutes.) The sounding from 00:05 UTC (about an hour after sunset) shows a completely saturated cloud of 500 m thickness from 700-1200 m altitude. The sounding from 18 UTC (~13:30 local, following the peak of incident solar radiation) shows two subsaturated moist layers. From visual observations, there were two layers of clouds on October 25, 18 UTC. Figure 71 shows a photograph taken by E. F. Bradley of cumulus rising into stratocumulus. The relative humidity saturates at 96% between 1.1 and 1.3 km altitude. Judging from the saturation of the relative humidity data at 96%, and visual observation of a cloud layer at this time, it is possible that the humidity sensor on the radiosonde was not properly calibrated. The maximum humidity of the sub-cloud cumulus layer is at 800 meters altitude.

Images from the NOAA GOES-10 satellite show large mesoscale cells of order 100 km in the stratocumulus clouds toward the west, with increasing frequency and scale in the afternoon. Figure 72 is an example of a GOES-10 image from approximately 15:00 local, when the ship was at 82°W. Separated by a sharp boundary, a clear region adjoins the stratocumulus deck to the southwest. It is also possible that day-to-day synoptic variability influences the boundary layer depth, cloud structures and winds sampled along the ship transect.

Leg 4: Stratus Ocean Reference Station

The *Ron Brown* was on station in the vicinity of the 2006-2007 mooring and the 2007-2008 mooring locations for 6 days from October 26 (299) 9 UTC until October 31 (304) 12 UTC. Soundings were deployed every 4 hours from October 26, 12 UTC to November 1 (305), 0 UTC. Soundings were deployed as available every 6 hours after that for the remainder of the cruise.

Figure 73 shows the time-height series during the time the ship was stationed at the WHOI mooring location. The time series is quite stationary in the boundary layer. In the free troposphere, the potential temperature increases by about 2 K, and this has the effect of weakening the stability of the inversion. Winds in the free troposphere are seen to veer (turn clockwise) 180° during the 6 days from southerly of ~10 m s^{-1}, through westerly and northerly, to easterly of about 8 m s^{-1}. These day-to-week trends in the free troposphere are most likely related to synoptic variability.

Figure 73 also shows variability within the boundary layer. The light blue contours reaching down from the boundary layer top in the potential temperature section are an indication of moist stability due to cloud thermodynamic processes. Stable layers in the upper boundary layer are accompanied by plumes of high specific humidity that reach up from the surface.

Diurnal cycles are evident in the boundary layer in Figure 73. To see the diurnal cycle better, the soundings from the 6 days at the WHOI station are composited on the time of day. Figure 74 shows the resulting time-height section of the diurnal cycle. The diurnal cycle of the boundary layer inversion height is evident from the potential temperature. The inversion sinks at about 8 local and rests at about 1.4 km during daylight, rising slightly after sunset (18 local). At midnight the inversion rises sharply to a maximum height of 1.6 km.

The inversion diagnosed from the specific or relative humidity also follows the same cycle. The relative humidity (3rd panel, middle) shows a maximum in cloudiness at about 4 in the morning local time, and the specific humidity is also 1 g kg^{-1} greater. The maximum humidity in the cloud layer occurs when the inversion is highest in the early morning. Below 700 m, there are two maxima in the specific and relative humidity, at 6 and 18 local. The surface humidity maximum at 6 is when the PBL is coldest and the stratocumulus cloud layer is thickest. There is also a surface wind speed maximum at 6. The humidity maximum at 18 local occurs when the PBL is just beginning to deepen. The relative humidity shows the influence of decoupling on the cloud vertical profile, with a local maximum of relative humidity at about 500-600 m.

Drizzle and light rain were observed while on station here. Precipitation is not measured by rawinsondes, but it is an important process in the budget and vertical distribution of PBL moisture. As the optical rain gauge malfunctioned during this cruise, we hope to recover a measure of precipitation from the radar wind profiler.

The meridional velocity is steadily about 5-7 m s^{-1} southerly in the boundary layer and 0-3 m s^{-1} above the boundary layer, with a clear decrease in the wind at the inversion. The zonal wind is 6-

8 m s^{-1} easterly in the boundary layer, with a ~500 layer above the PBL in which the zonal wind gradually tapers to zero. The zonal wind profile follows the inversion height (diagnosed from thermodynamic scalars) from 18 in the evening to 8 the next morning. While the inversion subsides at 8, the zonal wind stays strong in the free troposphere above the inversion (1.4-1.6 km altitude) in the daylight hours, and only collapses back to the inversion height at 18 in the evening. Below 500 m the winds are southeasterly, with a maximum at 6 local. This maximum in wind speed is coincident with the 6 AM maximum in humidity in the lower boundary layer. Climatological southeasterly advection is cold and dry, so perhaps local turbulent evaporation is responsible for this humidity maximum.

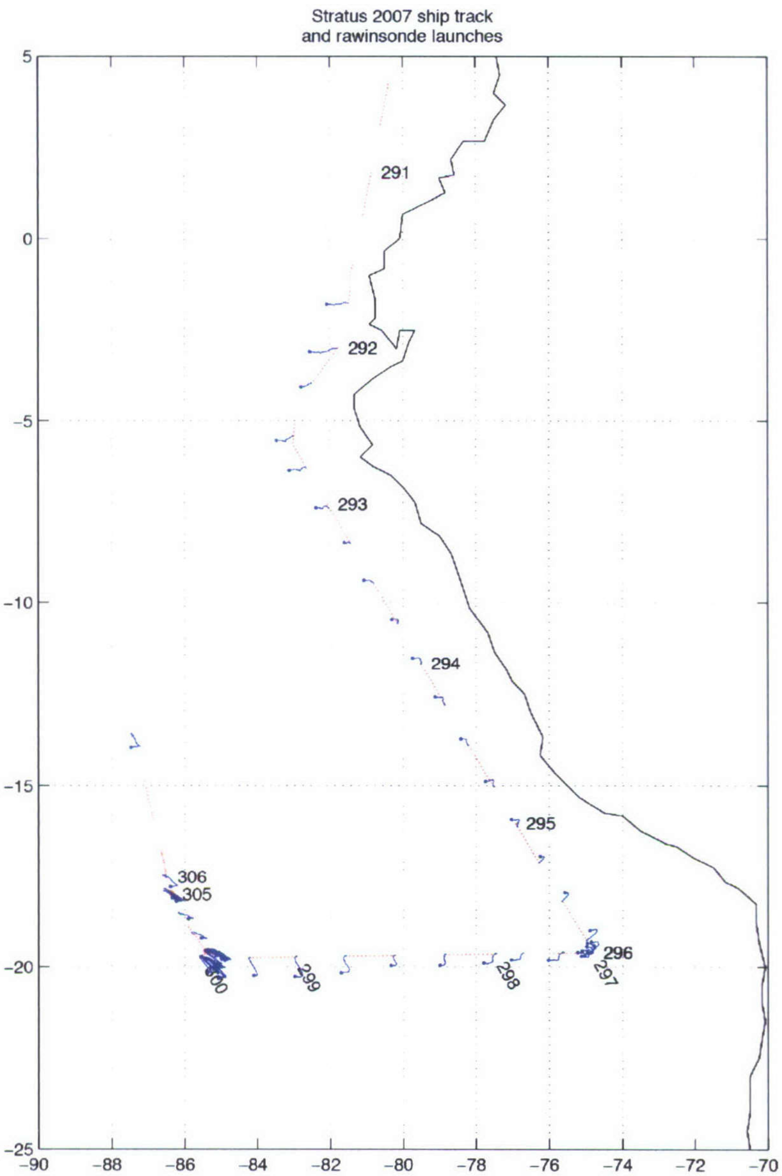

Figure 60: Track of the *Ron Brown* (red) with tracks of GPS rawinsondes (blue) superimposed. Numbers along the track indicate the yearday.

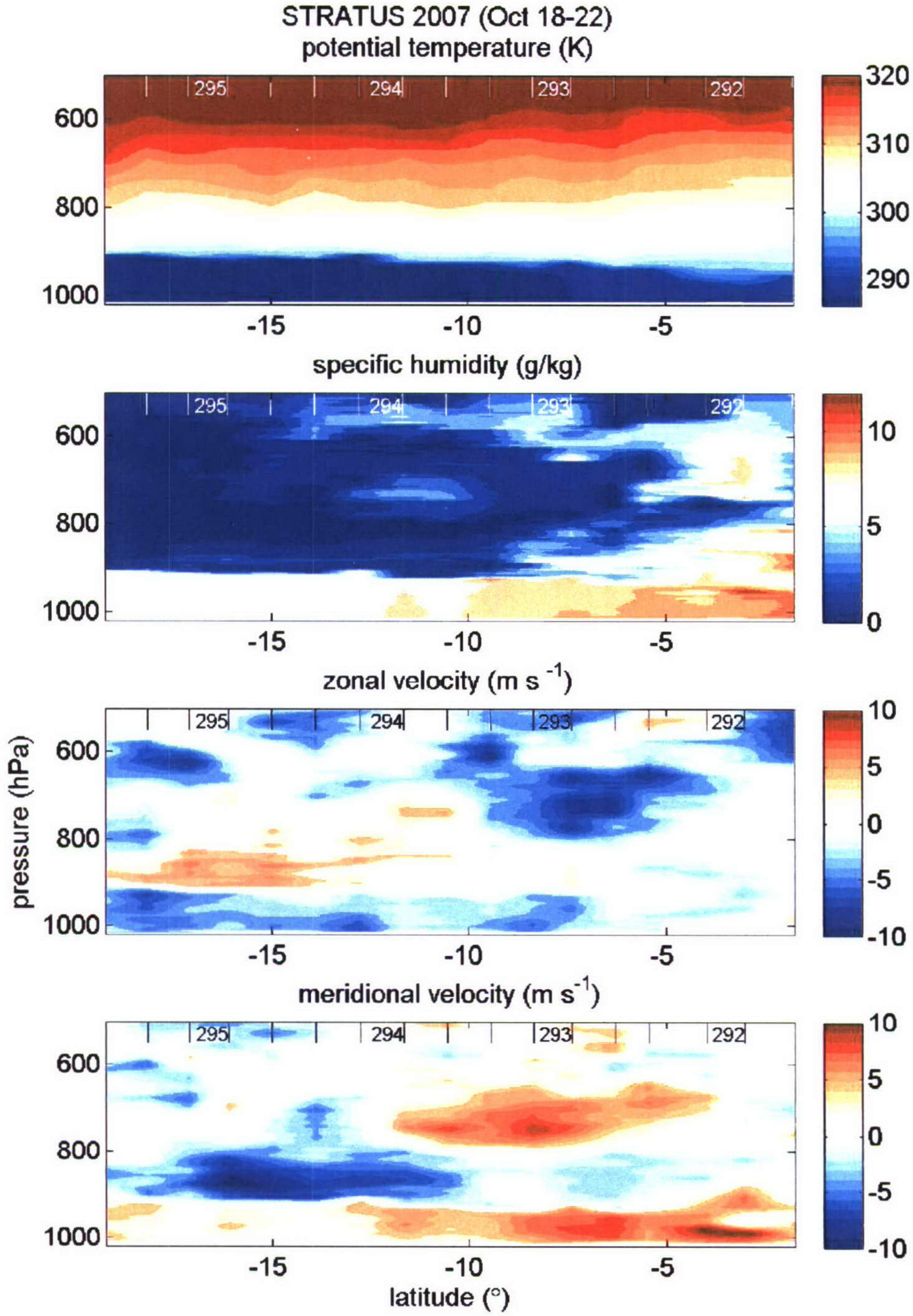

Figure 61: Cross section of observations from rawinsondes. Top panel shows potential temperature (° C), second panel shows specific humidity (g kg^{-1}), third panel shows zonal wind (m s^{-1}), and bottom panel shows meridional wind (m s^{-1})

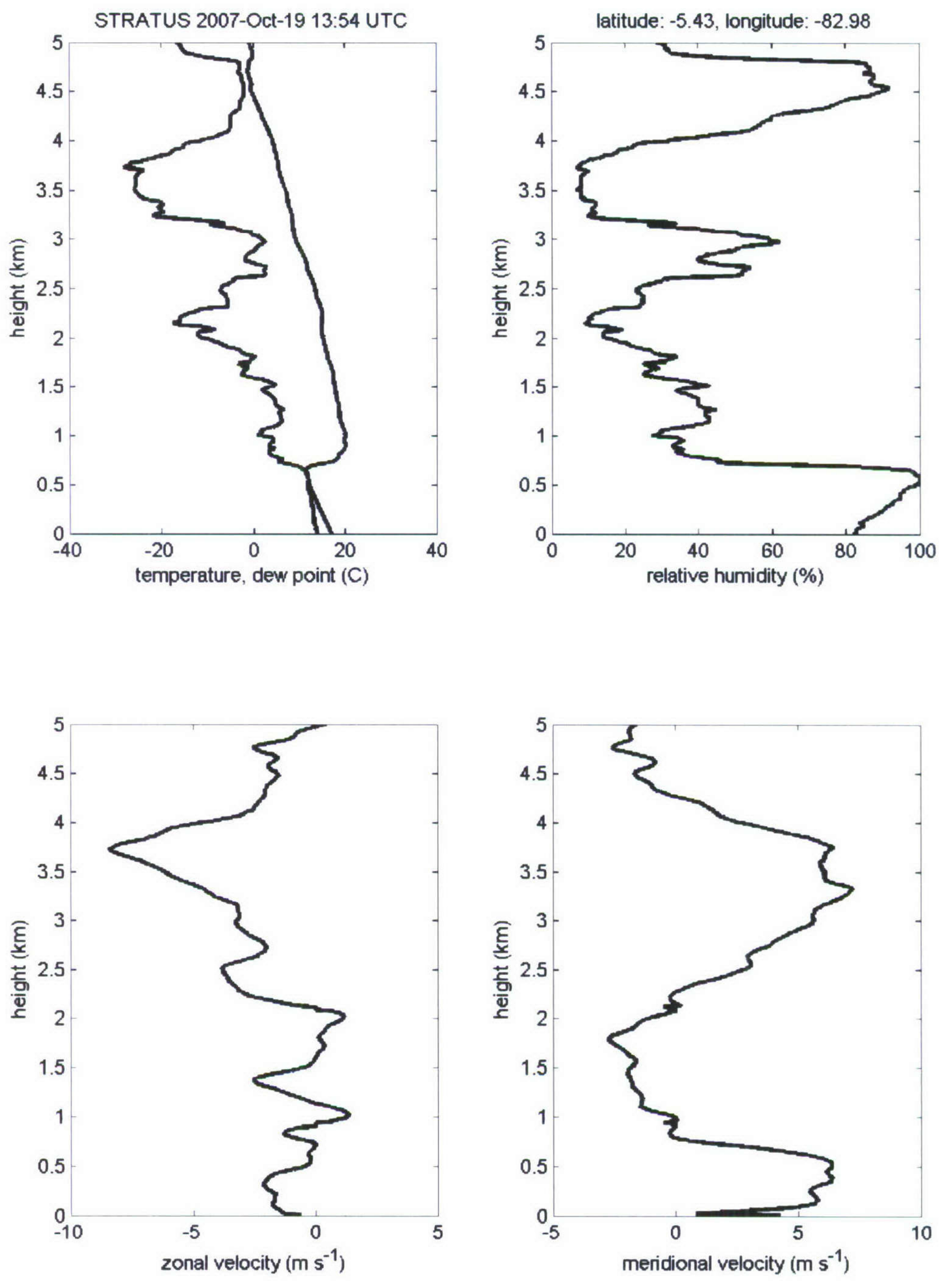

Figure 62: Sounding with stratus cloud in the convectively disturbed region at 83° W, 5.4° S. The top left panel shows temperature and dew point temperature (° C), the top right panel shows relative humidity (%), the bottom left panel shows zonal wind (m s^{-1}), and the bottom right panel shows meridional wind (m s^{-1}).

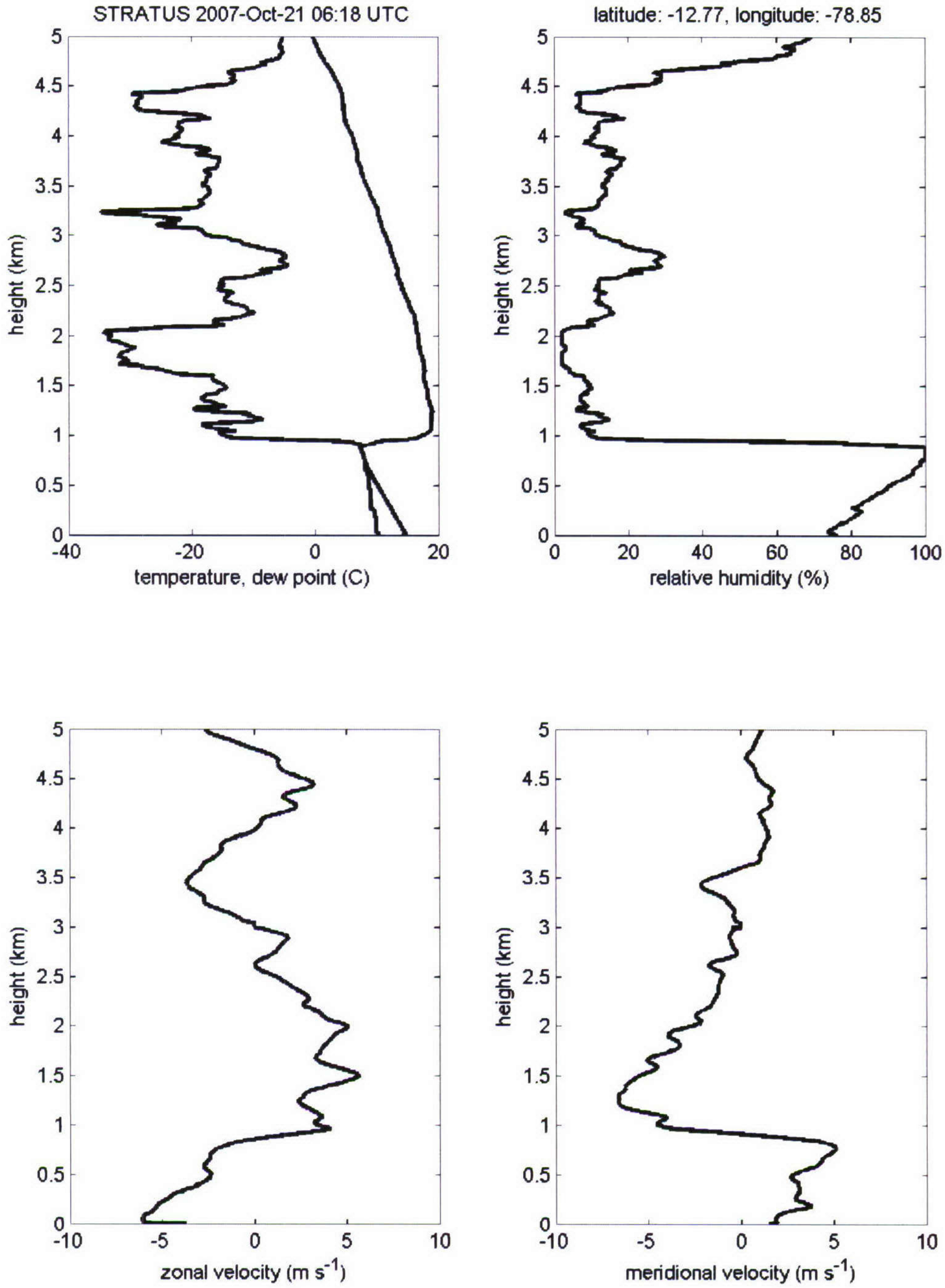

Figure 63: Sounding at 78.9°W, 12.8°S shows a typical thin stratocumulus cloud layer beneath a dry free troposphere.

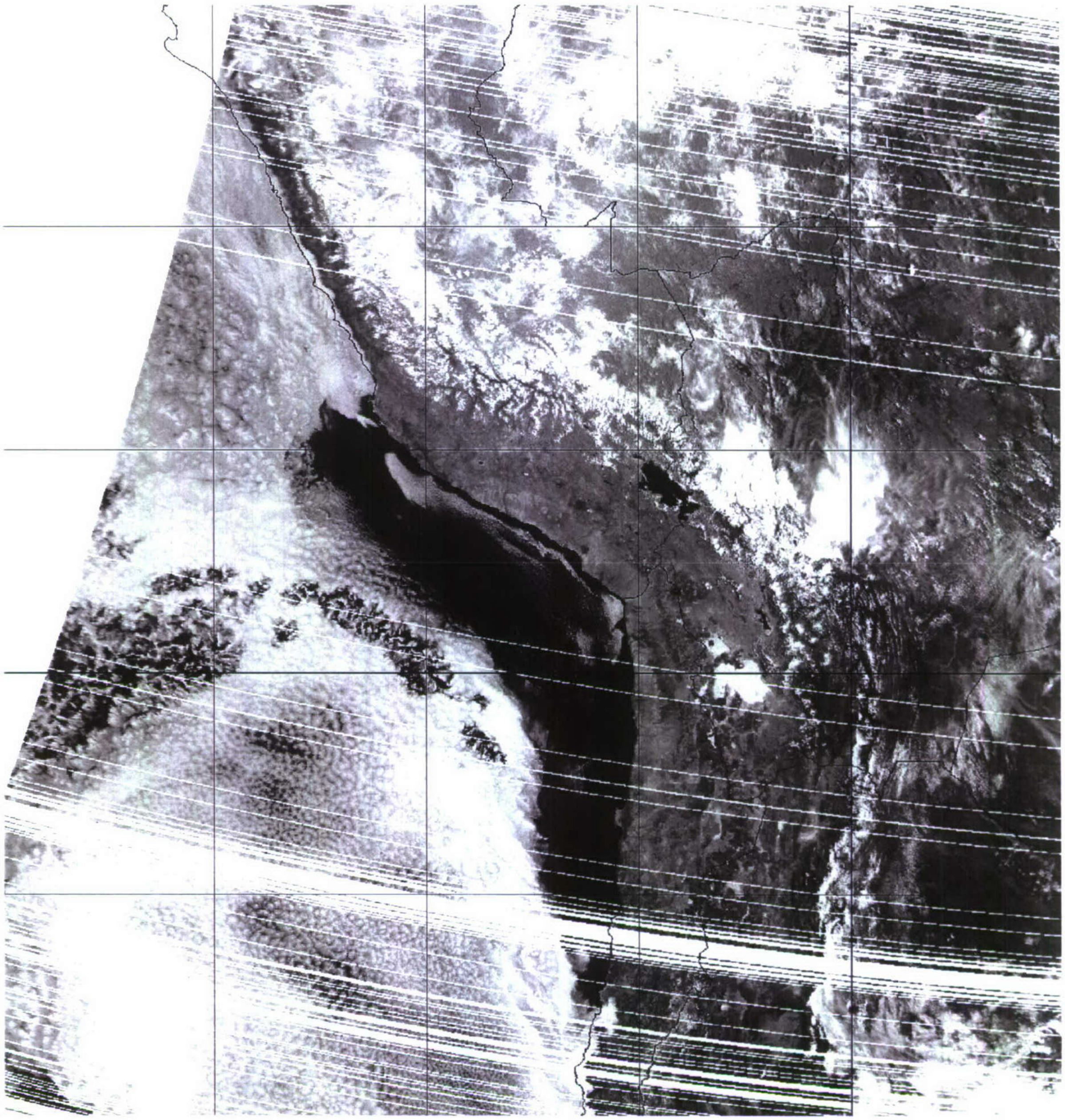

Figure 64: Visible radiance from NOAA-17 polar-orbiting satellite on October 22 at 14:25 UTC. The ship traveled south along 75°W from the strip of clouds between the pocket of open-cellular convection (POC) and the coastal clear region, into the POC.

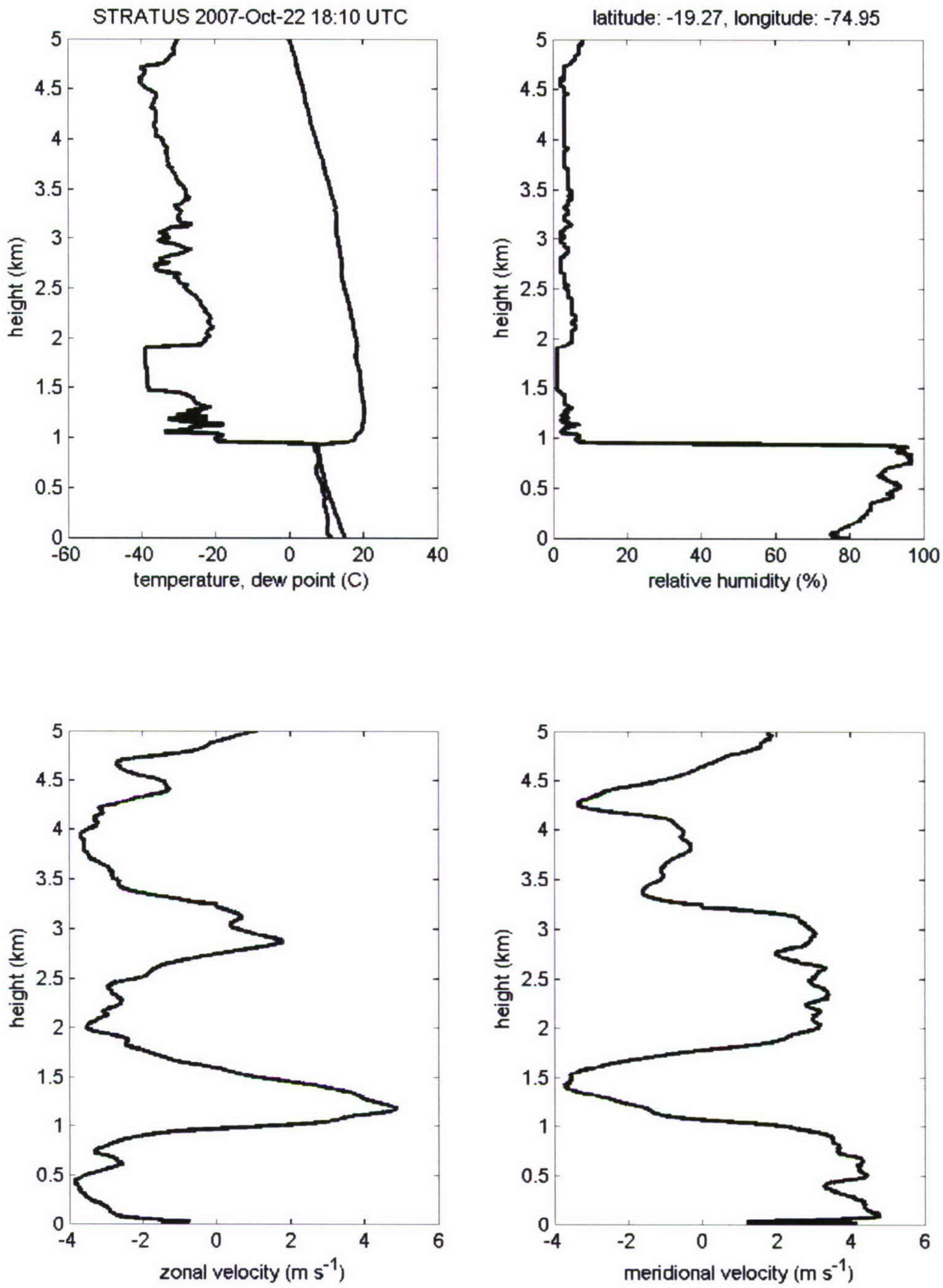

Figure 65: Radiosonde sounding of thermodynamic structure of the atmosphere in the POC, October 22, 18:10 UTC. A decoupled marine atmospheric boundary layer (MABL) is observed, with two subsaturated moist layers at the MABL top.

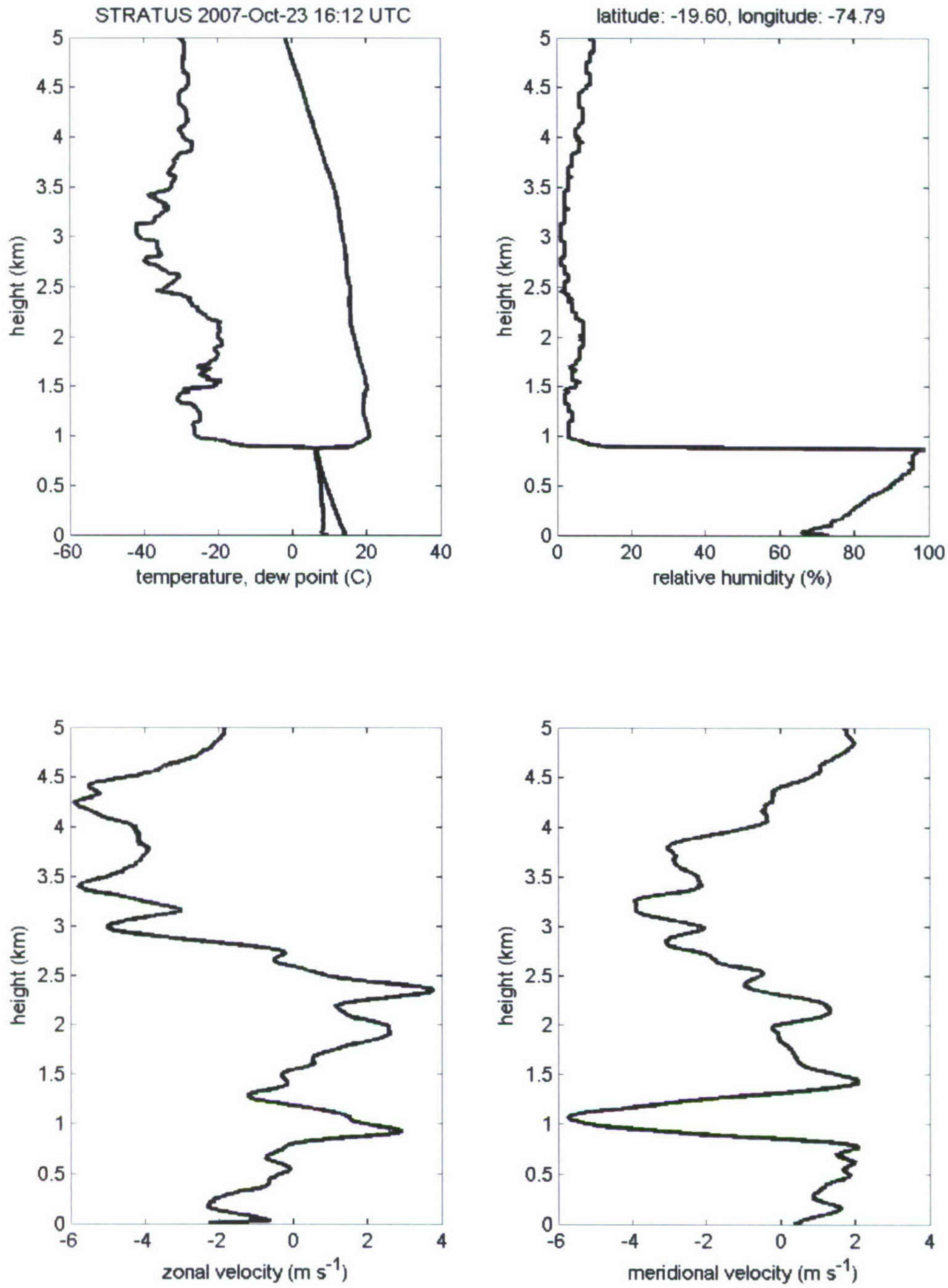

Figure 66: Rawinsonde of afternoon clearing conditions on October 23, 16:12 UTC.

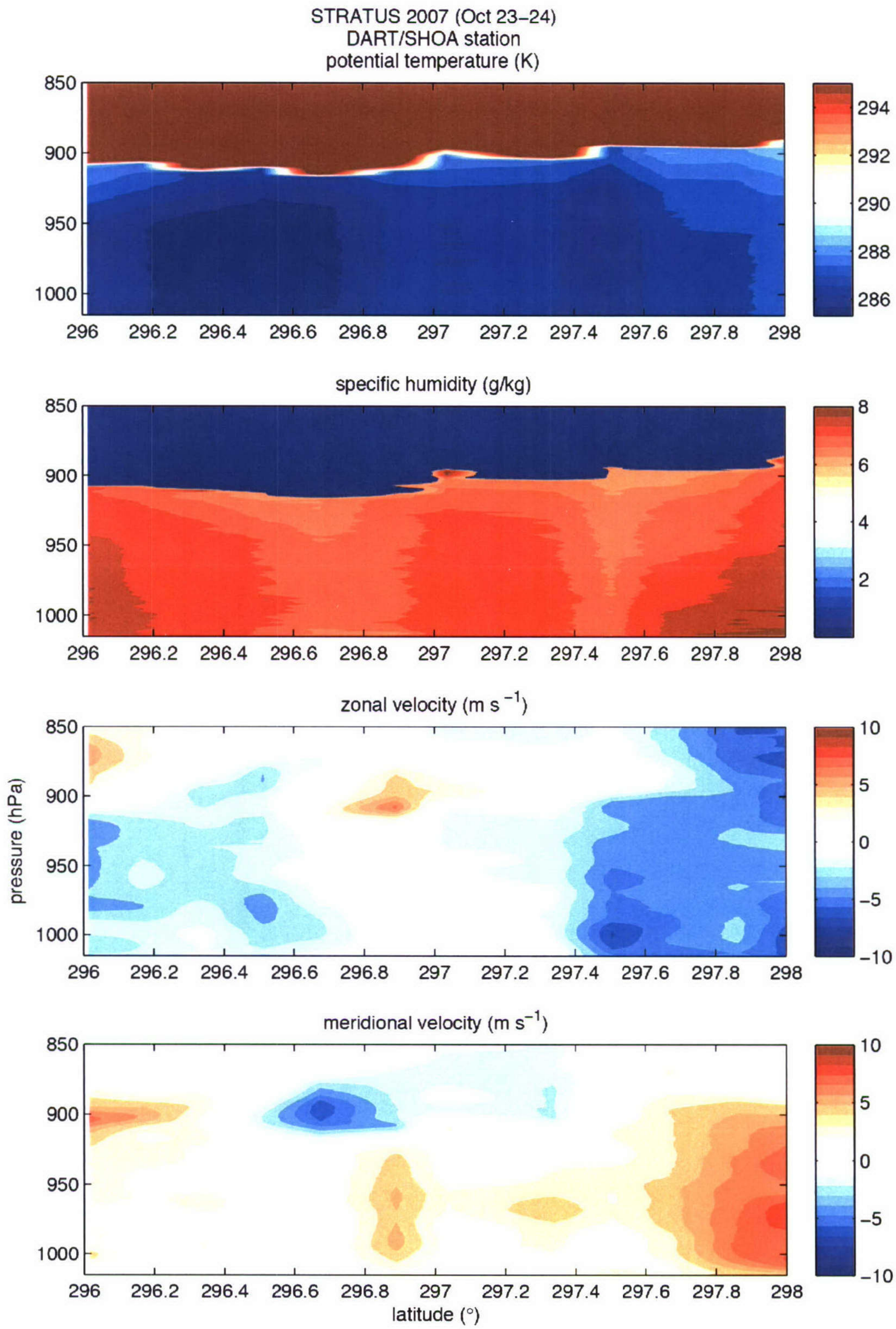

Figure 67: Time-pressure sections of potential temperature, specific humidity, and velocity components from two days of soundings at the SHOA/DART buoy location.

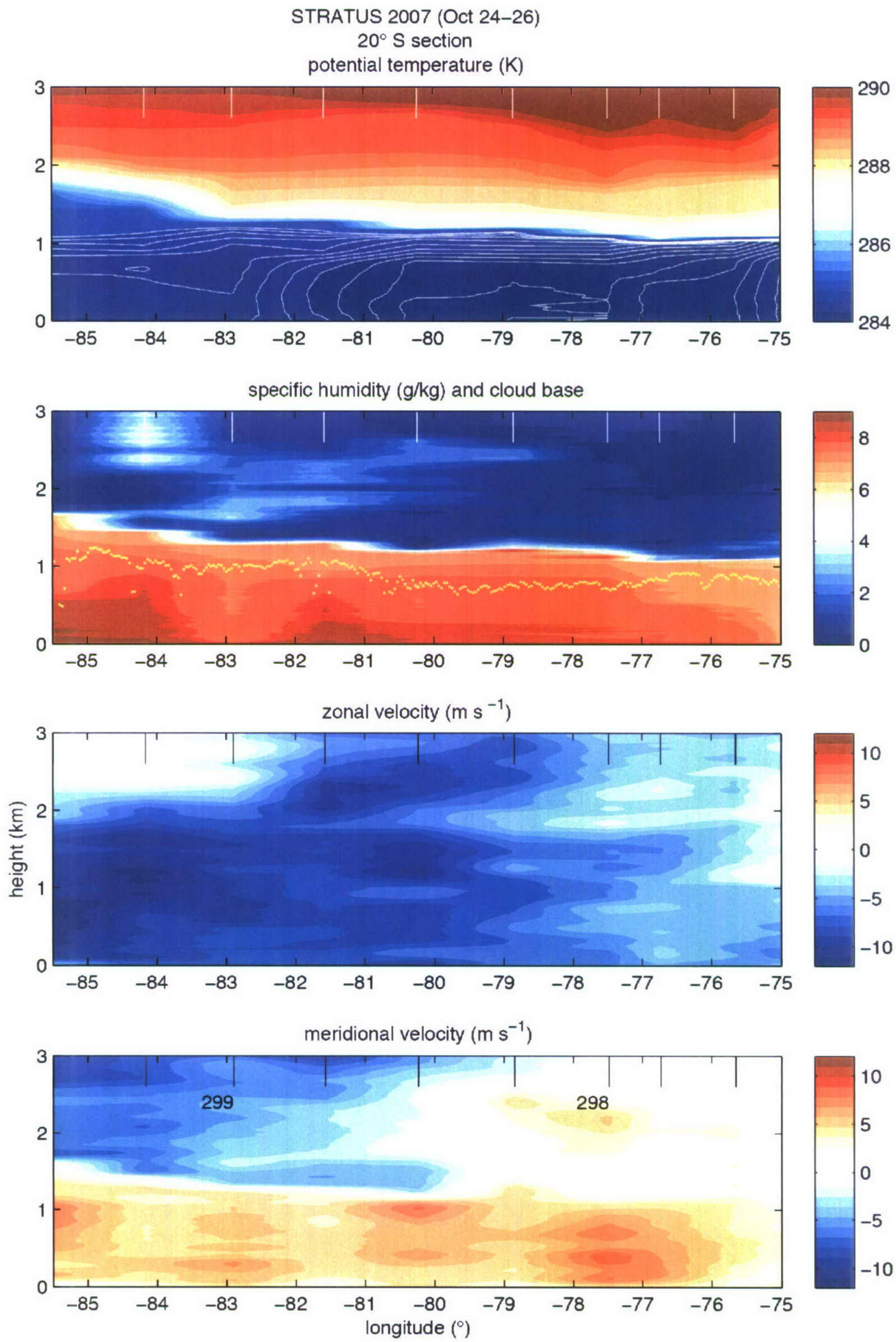

Figure 68: Zonal sections of potential temperature (white contour interval 0.25°C), specific humidity (ceilometer cloud base, yellow dots), and velocity components along 20°S. Long vertical ticks at the top of the plots indicate the times at which soundings were released.

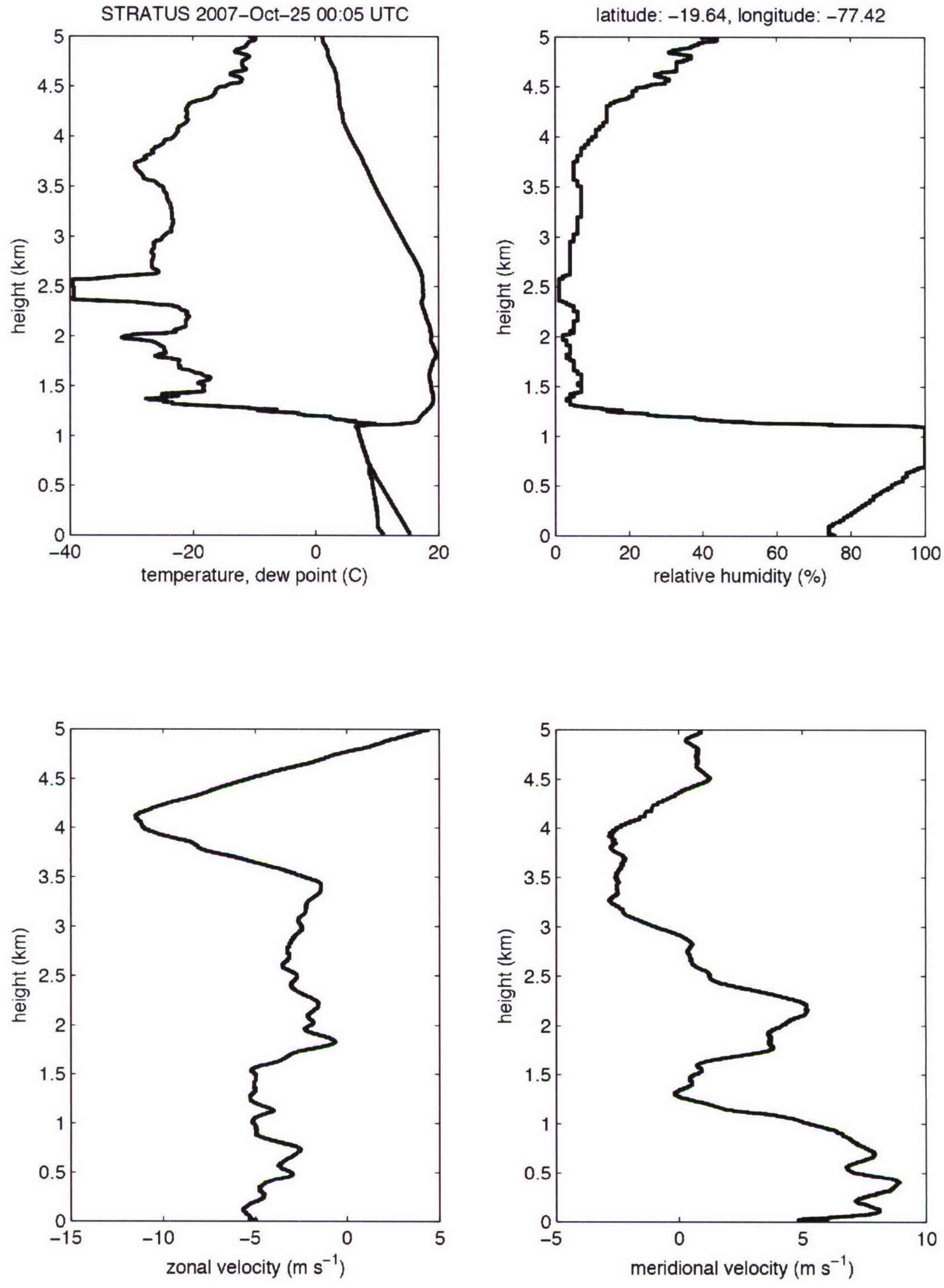

Figure 69: Rawinsonde sounding of the nearly unbroken stratus deck at 19.6°S, 77.4°W. The cloud layer is completely saturated and coupled to the mixed subcloud layer.

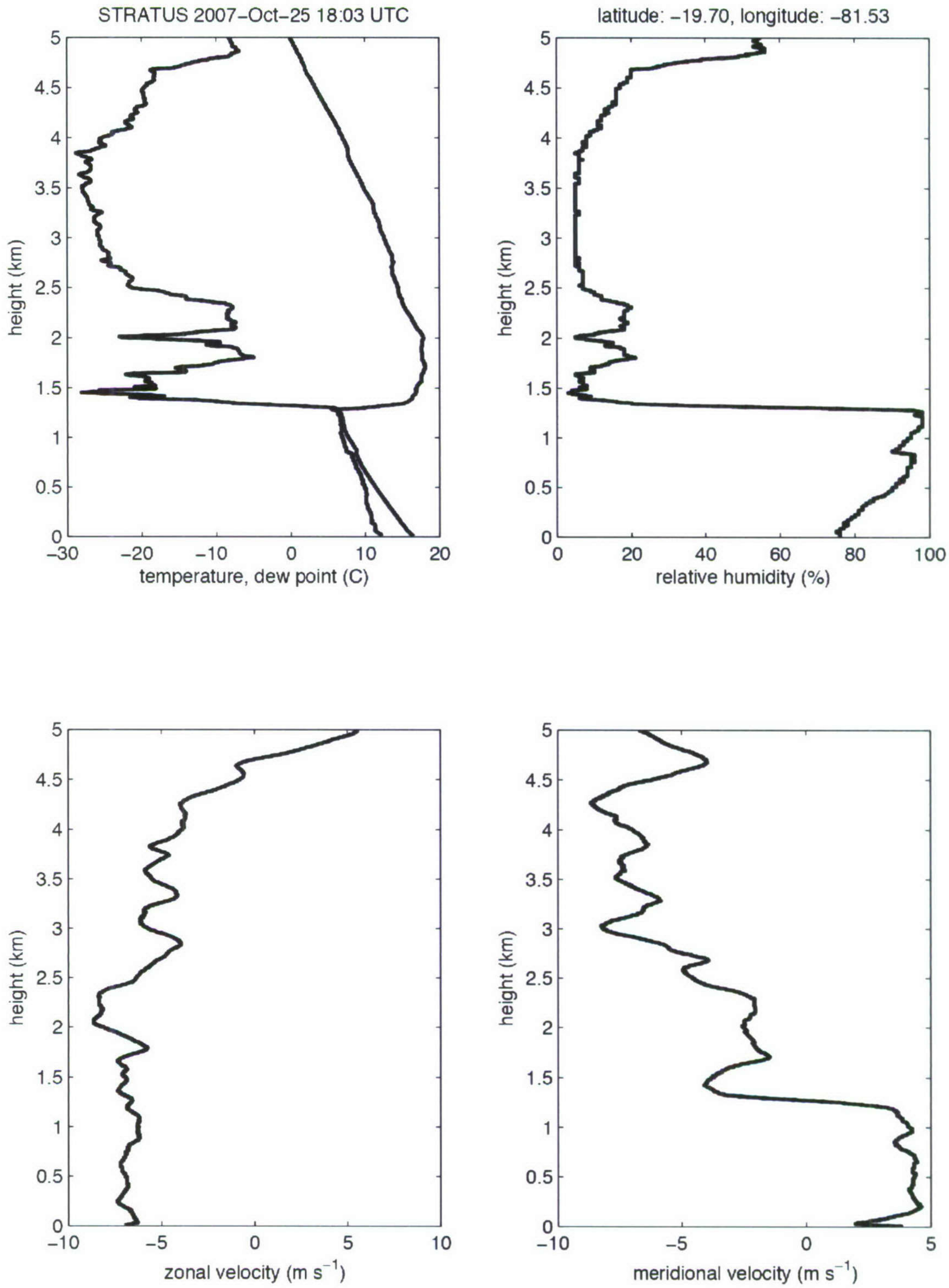

Figure 70: Sounding 18 hours after Figure 69, at October 25 (298) 18:03 UTC, or 13 local.

Figure 71: Clouds off the starboard side of the ship photographed by E. F. Bradley on October 25 (298) 18:00 UTC. Two layers of cloud, cumulus rising into stratocumulus, are observed.

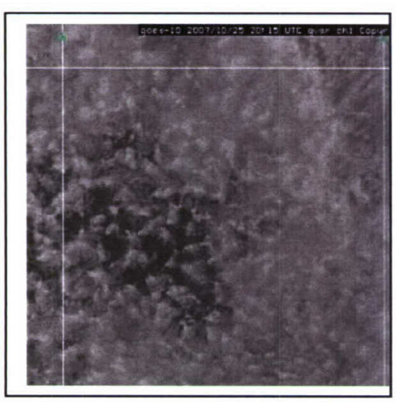

Figure 72: NOAA GOES-10 visible satellite image from day 298 (October 25, 20:15 UTC, ~16 local) of stratocumulus clouds becoming organized on larger scales and clearing slightly to the west. At this time the ship was at 19.7°S, 82.1°W.

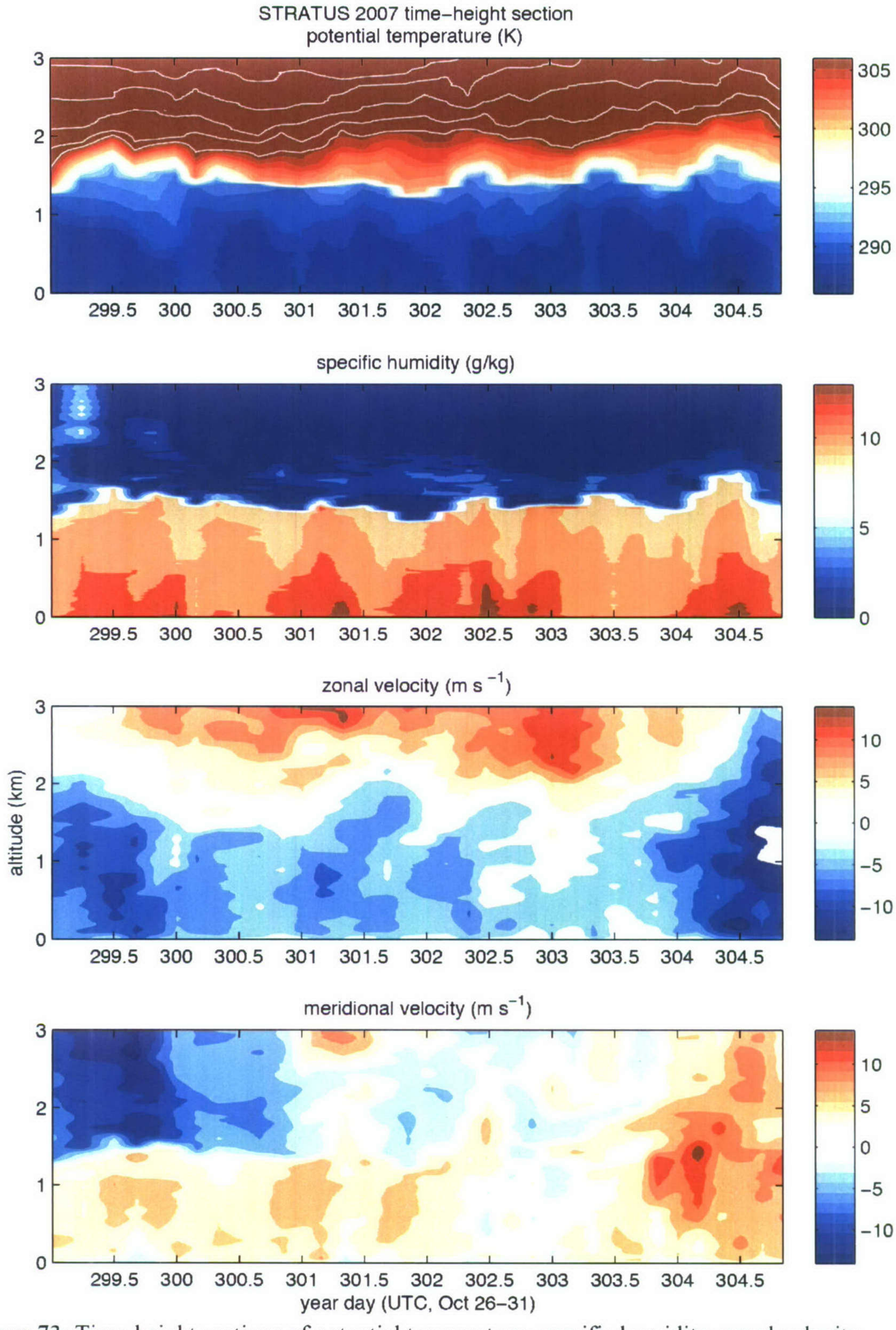

Figure 73: Time-height sections of potential temperature, specific humidity, zonal velocity, meridional velocity while the *Ron Brown* was on station at the WHOI buoy location near 20°S, 85°W.

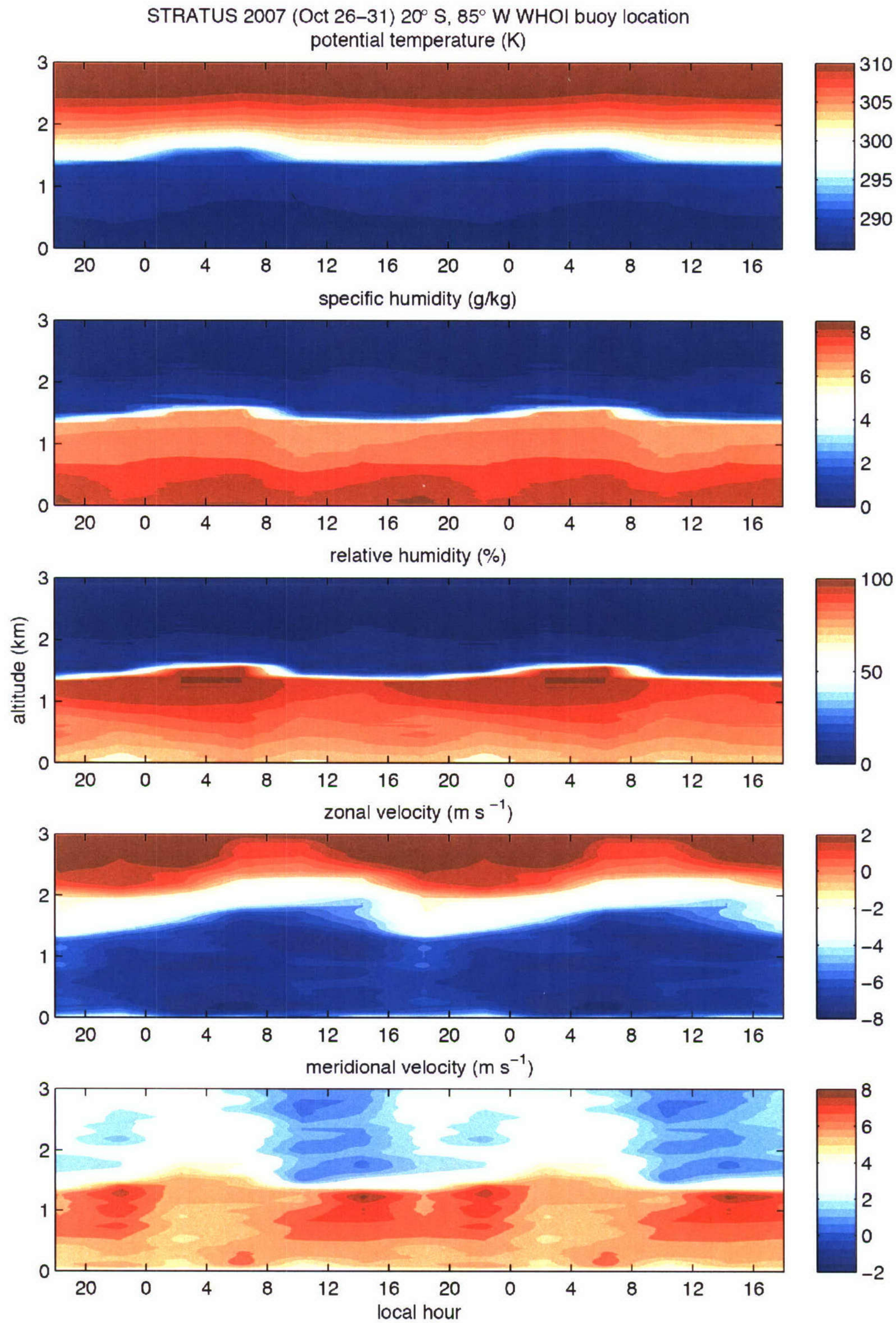

Figure 74: The diurnal cycle of potential temperature, specific humidity, relative humidity, and wind components for the period the ship was at the WHOI mooring station. Two diurnal cycles are shown.

10. SHOA DART

Overview

The DART (Deep-Ocean Assessment and Reporting of Tsunami) Project was created in order to efficiently and quickly confirm the generation of a potentially destructive tsunami, as well as to support the ongoing effort to develop and implement an early detection capability and real-time report of tsunamis in the deep ocean. This project was created as part of the National Tsunami Hazard Mitigation Program (NTHMP) of the United States.

For the STRATUS 2006 cruise, the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA) acquired and deployed a DART II system for its early tsunami detection and real-time reporting capability.

The DART mooring system is illustrated in Figure 75 and Figure 78. The system consists of a seafloor Bottom Pressure Recorder (BPR) and a moored surface buoy with related electronics for real-time communications. The BPR uses a pressure transducer manufactured by Paroscientific, Inc., to make 15-second averaged measurements of the pressure exerted on it by the overlying water column. These transducers use a very thin quartz crystal beam, electrically induced to vibrate at their lowest resonant mode. In DART II applications, the transducer is sensitive to changes in wave height of less than a millimeter. An acoustic link is used to transmit data from the BPR on the seafloor to the surface buoy. The data are then relayed via Iridium satellite link to ground stations, which demodulate the signals for immediate dissemination to Sistema Nacional de Alarma de Maremotos (SNAM) in SHOA, via internet.

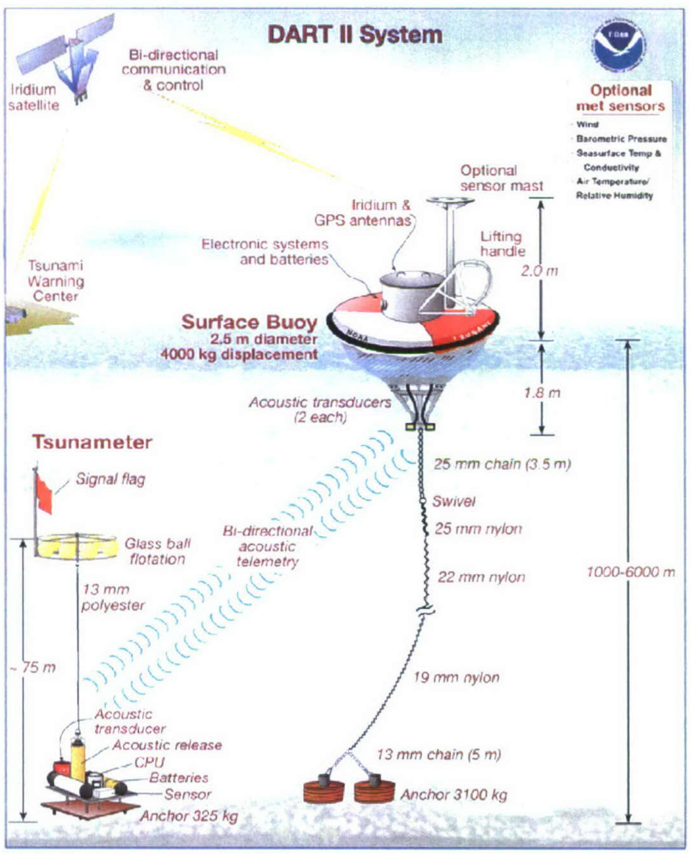

Figure 75: Schematic of the Typical DART mooring system

Enhanced Dart Surface Mooring

The SHOA DART II buoy, deployed on October 23th 2006, received a set of meteorological and subsurface instruments from WHOI's UOP group. The surface buoy was instrumented with wind speed and direction, as well as longwave, and shortwave radiation sensors. It also carried two low-cost humidity sensors that were tested during the 06/07 deployment period. The surface modules are stand-alones units with no logger or telemetry. Subsurface instruments were Brancker XR420 conductivity and temperature loggers, and Brancker TR-1050 temperature loggers. Figures 76 and 77 show subsurface instrumentation.

Instrument	Serial	Depth
XR420-CT	12942	10
XR420-CT	12943	20
XR420-CT	12944	50
XR420-CT	12945	92.5
XR420-CT	12946	145
TR-1050	12694	1 bridle
TR-1050	12695	30
TR-1050	12696	40
TR-1050	12697	62.5
TR-1050	12698	77.5
TR-1050	12699	115
TR-1050	12700	175
TR-1050	12701	220
TR-1050	12702	250
TR-1050	12703	310

Figure 76: SHOA DART Subsurface Instruments

Buoy Release	WHOI 31268
BPR Release	31240

Figure 77: SHOA DART Releases

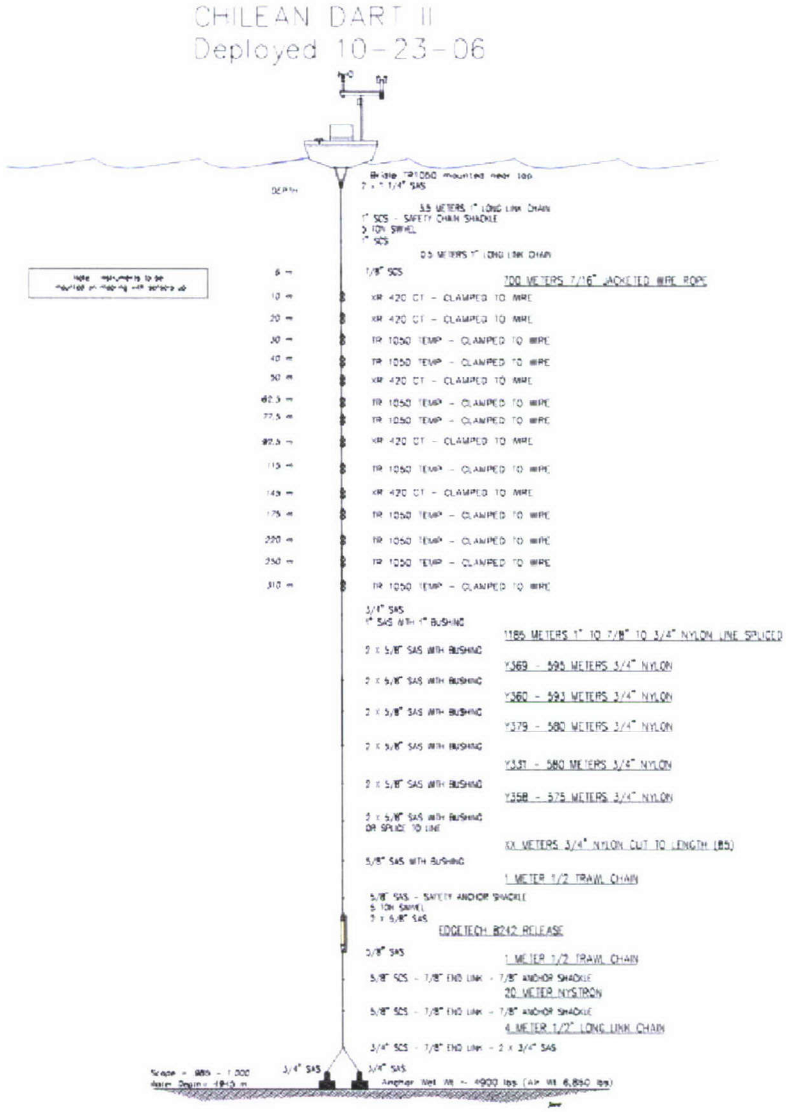

Figure 78: SHOA DART BUOY

2007 Dart Buoy Maintenance

On October 23, 2007, the *R. H. Brown* stopped at the SHOA DART buoy to change out meteorological sensor modules as part of the STRATUS 8 cruise. The small rescue boat was used to carry personnel to the buoy to perform this scheduled maintenance. Long wave and short wave radiation modules and the wind module were replaced. The two low-cost humidity sensors were replaced with a WHOI ASIMET humidity/temperature module. An additional battery was installed to power the humidity/temperature sensor for the next year. The batteries installed on the buoy during the STRATUS 2006 cruise will power the rest of the modules for another year. Figures 79, 80, 81 show the service of the DART ASIMET modules.

Figure 79: Service of SHOA DART buoy.

Module	Serial	Firmware Version
HRH	502	VOS HRH53 V3.2
WND	214	VOS WND53 V3.5
LWR	208	VOS LWR53 V3.5
SWR	202	VOS SWR53 V3.3

Figure 80: SHOA DART IMET modules deployed.

Module	Serial	Firmware Version	Height Cm	Sample Rate
WND	344	VOSWND53 V3.5	245	5min
LWR	213	VOSLWR53 V3.5	232	5min
SWR	201	VOSSWR53 V3.3	231	5min
LASCAR	5			1hr

Figure 81: SHOA DART IMET modules recovered.

11. NDBC DART

10/02/2007
NDBC DART Technicians James Coleman and Russell Spiers began loading all necessary DART equipment onto the NOAA Ship *Ron H. Brown* in Charleston, SC. The DART system intended for deployment was then put into testing.

10/04/2007
The Dart system was powered down and moved to accommodate all other science party's equipment to be secured on the ship's deck.

10/29/2007
The DART system was powered up for its final testing prior to deployment.

10/31/2007
The working deck on the ship was set up to deploy DART Station 32412. The buoy was positioned on the port side and the mooring was positioned on the starboard side. The BPR (Bottom Pressure Recorder) remained at its position near the fantail until deployment.

11/01/2007
Deployment operations began at 1200 UTC. The buoy was placed in the water securely using tag lines securing both sides of the buoy and on the bridle. It was deployed on the port side while 200m of nilspin wire was payed out. The remaining 4094m of nylon mooring was connected and payed out the fantail of the ship. The end of the mooring was secured using a double chain stop secured at the fantail. The buoy anchors were then positioned at the fantail for deployment. They were then lifted by a winch through the A-frame while being secured by tag lines. The anchors were deployed at 14:46 UTC at position 17°58'30S , 86°23'30W. The operations team waited approximately an hour for the anchors to settle before starting BPR deployment operations. At approximately 16:00 UTC, BPR deployment operations were initiated. NDBC DART Technician Russell Spiers had previously constructed the BPR's mooring and floats which made deck operations start without delay. The glass ball floats were payed out as did all mooring. The BPR was secured with a winch and tag lines. The BPR was lifted by the winch and deployed at 16:43 UTC at position 17°58'19S , 86°23'31W. Permission was granted from the bridge to lower the Benthos transducer to receive BPR messages as it descended to the ocean floor. Although data was transmitted by the buoy on the secondary system, the primary had no data. Permission was granted at approximately 17:30 UTC to do take a small boat to the DART buoy to correct the primary system problem. NDBC Technician James Coleman transferred onto the buoy to connect to the primary system. Confident the problem was resolved, the small boat crew returned to the ship. Data was comparable on my primary and secondary systems of the buoy. Prior to being released from station, Jeff Lord from WHOI assisted NDBC Dart technicians on triangulating a location of the BPR on the ocean floor. Team was released from station at approximately 19:00 UTC.

Website:
http://www.ndbc.noaa.gov/station_page.php?station=32412

NDBC DART Buoy/BPR info

Dart buoy anchor over 17 58.279 S, 86 23.304W Heading 113
Dart buoy target (estimate) ~17 58.217S, 86 23.461W
Separation between estimated position of anchor and calculated position of BPR = 83.2 meters @ heading 051.57 degrees.

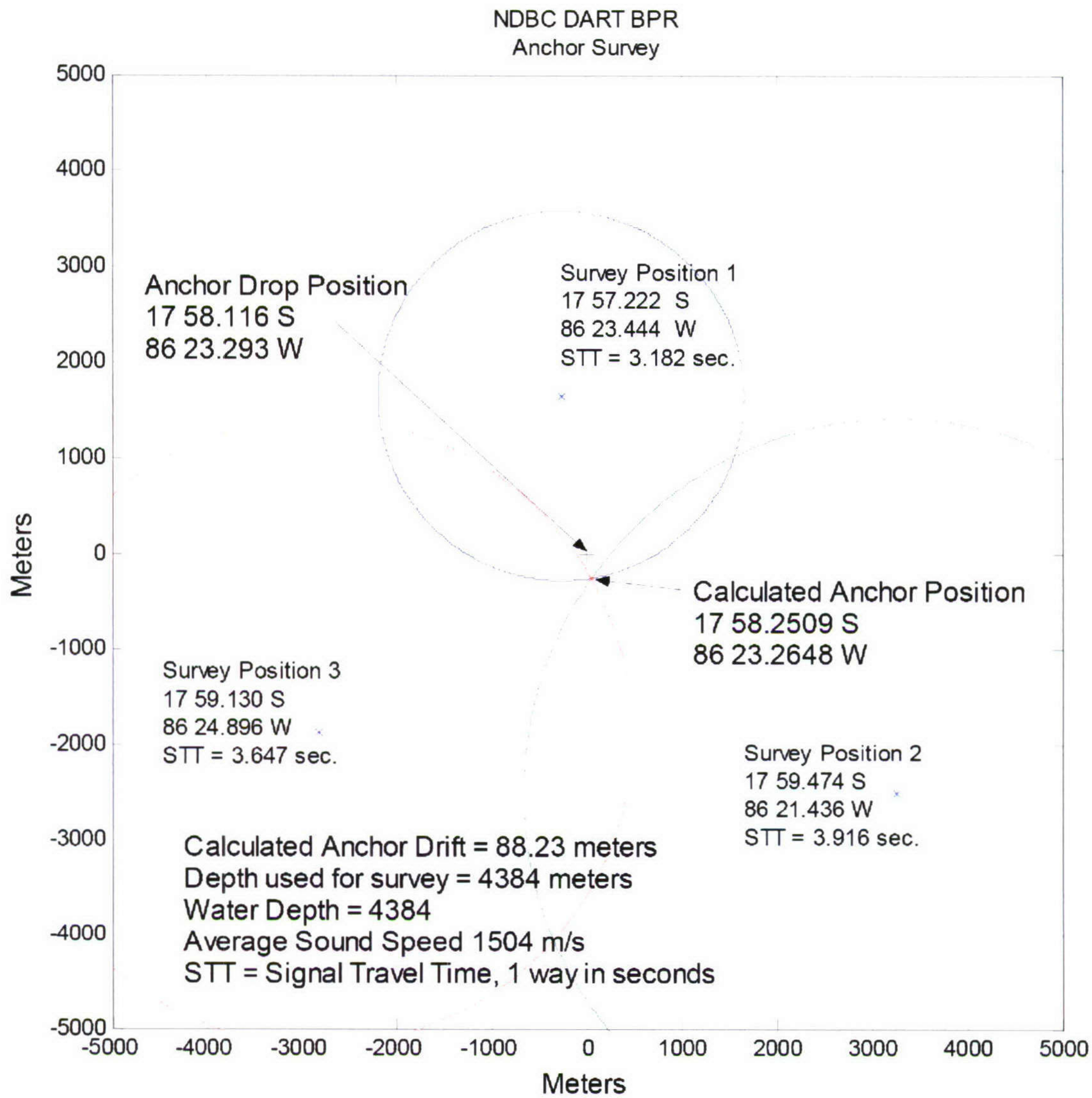

Figure 82: NDBC DART BPR Anchor Survey

12. Deployment of Argo Floats and Drifters

During the Stratus 2007 cruise, a 24-hour under way watch schedule was established. Watch standers were responsible under way CTD casts, and for Argo float and surface drifter deployments.

Argo (*http://www.argo.net/)* is an international program using autonomous floats to collect temperature, salinity, and current data. A broad-scale global network of profiling floats, 3° by 3° spaced is being implemented (since late 1999) and will be maintained, as a major component of the ocean observing system.

The modern surface drifter, shown in Figure 83, is a high-tech version of the "message in a bottle". It consists of a surface buoy and a subsurface drogue (sea anchor), attached by a long, thin tether. The buoy measures temperature and other properties, and has a transmitter to send the data to passing satellites. The drogue dominates the total area of the instrument and is centered at a depth of 15 meters beneath the sea surface. More information on the Global Drifter Program can be found at http://www.aoml.noaa.gov/phod/dac/gdp.html. The global array is shown in Figure 84.

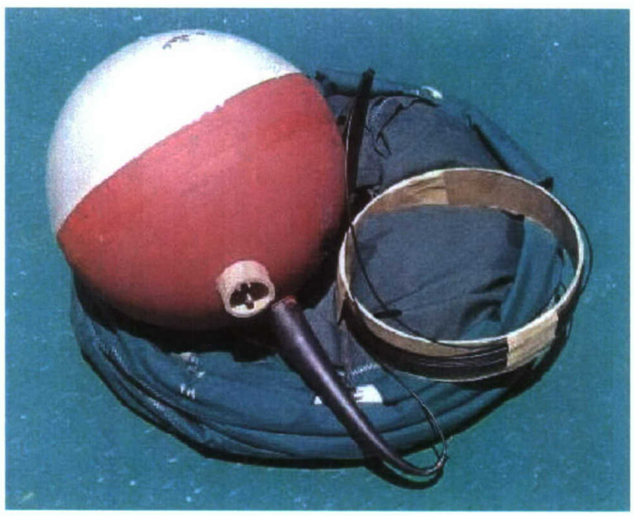

Figure 83: Typical Surface Drifter

The floats and drifters were deployed at specified locations. The ship was not slowed for deployments of the Argo floats or surface drifters. Deployment details are shown in Figures 85 and 86.

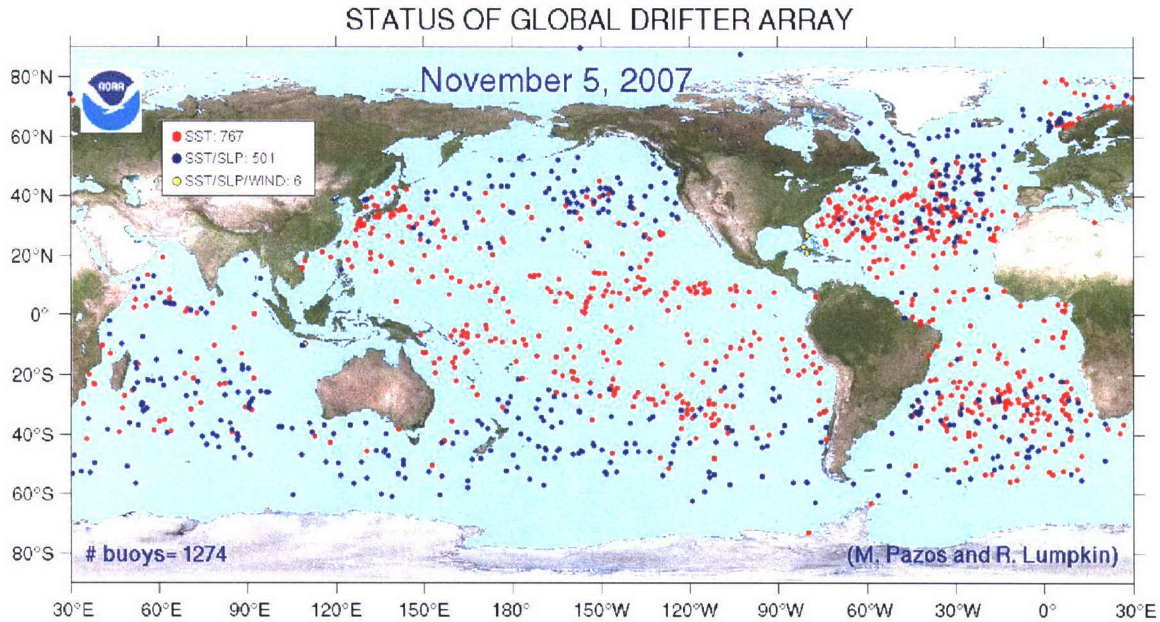

Figure 84: Global deployment of drifters.

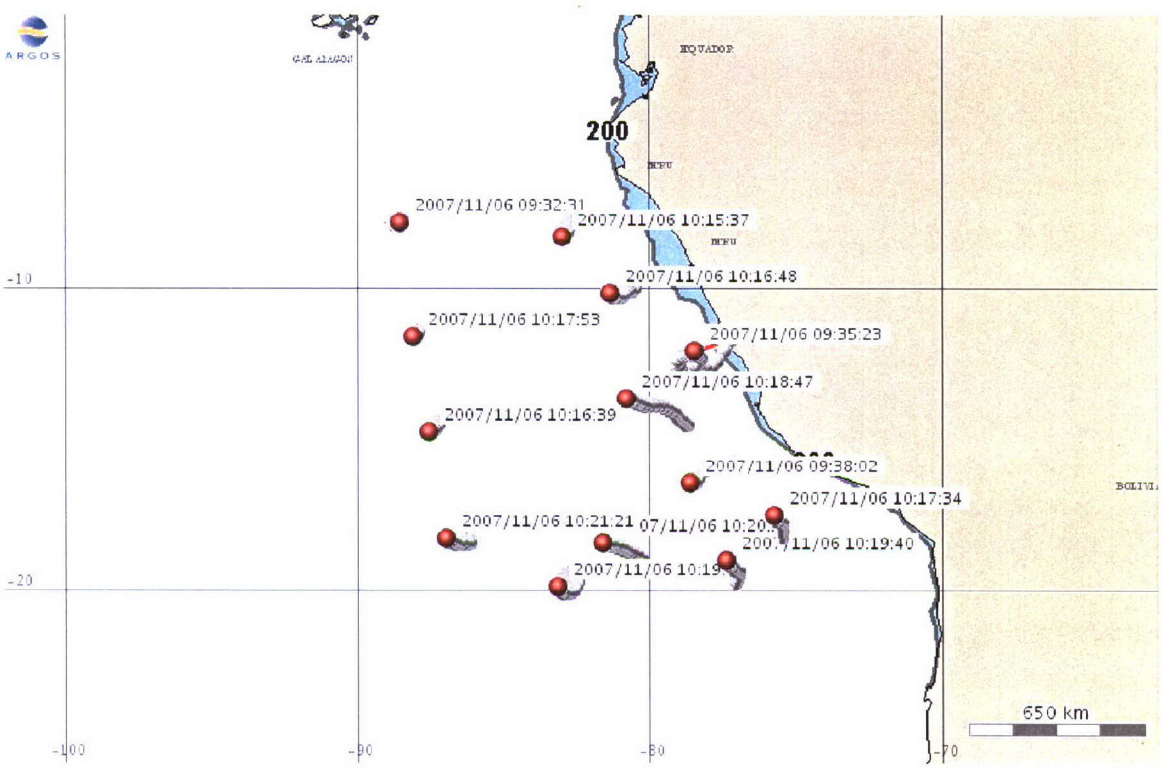

Figure 85: Deployment times and locations for the SVP drifters.

DRIFTER ID	DATE/TIME (UTC) OF START UP	DEPLOYMENT DATE/TIME	DEPLOYMENT POSITION
DRIFTER 1 71195	NA	10/19/07 22:35	07 00 S 82 13.2 W
DRIFTER 2 71185	NA	10/20/07 12:18	09 29 S 80 46 W
DRIFTER 3 71192	NA	10/20/07 23:16	11 30 S 79 37 W
DRIFTER 4 71196	NA	10/21/07 12:27	13 56 S 78 09 W
ARGO 1 785	10/21/07 17:45	10/21/07 17:50	14 56.5 S 77 33.6 W
DRIFTER 5 71200	NA	10/22/07 2:50	16 30 S 76 37 W
ARGO 2 786	10/21/07 18:05	10/22/07 5:33	17 00 S 76 19 W
DRIFTER 6 71208	NA	10/22/07 16:19	18 56 S 75 09 W
ARGO 3 782	10/24/07 14:39	10/24/07 17:53	19 37 S 76 01 W
DRIFTER 7 71198	NA	10/25/07 11:15	19 38 S 76 59 W
ARGO 4 781	10/24/07 21:03	10/25/07 2:40	19 38 S 78 01 W
DRIFTER 8 71175	NA	10/25/07 11:15	19 40 S 80 00 W
ARGO 5 787	10/25/07 18:35	10/25/07 20:15	19 42 S 82 01 W
DRIFTER 9 71180	NA	10/26/07 0:35	19 43 S 82 59 W
ARGO 6 788	10/25/07 22:45	10/26/07 5:08	19 44 S 83 59 W
ARGO 7 784	10/31/07 14:15	10/31/07 20:25	18 30 S 86 06 W
DRIFTER 10 71211	NA	10/31/07 20:38	18 28.81 S 86 07.31 W
ARGO 8 783	11/02/07 17:02	11/2/07 17:02	15 00 S 87 03 W
DRIFTER 11 71209	NA	11/2/07 19:49	14 28.65 S 87 10.72 W
ELDIN 1 D03	NA	11/3/07 8:30	12 03.7 S 87 44.5 W
DRIFTER 12 71207	NA	11/3/07 6:24	11 31.15 S 87 52.08 W
ELDIN 2 D06	NA	11/4/07 4:25	09 01.6 S 88 26.4 W
ARGO 9 779	11/03/07 17:15	11/4/07 11:20	08 01 S 88 40 W
DRIFTER 13 71176	NA	11/4/07 12:22	07 51.0 S 88 42.6 W
ELDIN 3 D09	NA	11/5/07 0:00	06 03.3 S 89 14. 3 W
ARGO 10 784	11/03/07 17:15	11/5/07 8:04	05 00 S 089 14.3 W
ELDIN 4 D05	NA	11/5/07 21:54	03 00 S 89 49.2 W

Figure 86: Deployment times and locations for the ARGO floats and drifters

13. Teacher At Sea

The Teacher at Sea Program began in 1990 and has taken more than 450 teachers to sea. The program allows teachers to work alongside scientists out at sea, thus giving them a unique and hands on experience. Teachers are in a wonderful position to be able to share this amazing experience with students in their school, as well as students from all over the country. Throughout our 30 day, cruise I kept a daily log that was posted on the Internet for any student or teacher to access at any time. Along with a description of what was happening scientifically on any given day, there were lesson ideas incorporated into the logs as well. All of the scientists on the trip were very willing to share their knowledge and experiences with me. This will make it that much better when I arrive back at school to share my experiences with the students and faculty at Truro Central School.

Part of my job on this trip was to conduct a sea surface temperature comparison between three different devices, a mercury thermometer, a YSI thermometer attached to a hose hanging into the water off the starboard bow of the ship, and the ship's SST device. It should be noted that the ship's thermometer, as well as the thermometer attached to the hose both read to the thousandth of a degree, whereas the bucket thermometer read to the whole degree. I took the sea surface temperatures each hour from each device for a number of days. Why, you might ask, would anyone hang a bucket over the side of the ship to test the temperature when there were two other sensors already measuring it? It is crucial when any research is being conducted that there are checks and balances across the board. From the graphics you can see that generally speaking the ship's SST was lower than the bucket thermometer as well as the thermometer attached to the hose off the bow of the ship. There were times, however, where the temperatures were very similar between the three instruments. It should be noted that the ship's thermometer was five meters below the surface of the water. Therefore, it can be deduced that on days where the sun was out and therefore, diurnal heating of the surface of the water occurred and the temperature would be higher in the bucket as well as the snake. When the sun did not come out, or there were larger waves causing more of a mixing in the upper five meters of the ocean, the temperatures were also quite similar. I feel that it is very good practice to check the instruments being used for research purposes.

I was also given the opportunity to launch weather balloons on a daily basis. These balloons were sent up four and sometimes six times per day. Each team was required to recondition radiosondes and send them into the atmosphere attached to a weather balloon. As the balloon ascended, it would send back data that was then shared with climate scientists as they create climate models. It was a fantastic experience to be involved in the research of the climate in the equatorial Pacific. There are so many connections made between the climate in this region and weather patterns and climate in other sections of the world. It was an honor and a privilege to be able to work alongside these cutting edge scientists as they performed their research. Many thanks to the Teacher at Sea Program as well as the Woods Hole Oceanographic Institution for allowing me to participate.

Acknowledgements

This project was funded through grants from the Office of Global Programs of the National Oceanic and Atmospheric Administration (NOAA Grant NA17RJ1223). The UOP Group would like to thank the crew of the R/V *Ronald H. Brown* and all of the scientific staff for their help during the Stratus 2007 cruise. Additionally, we would like to thank Jochen Klinke (Oceansciences) for his expertise, and enthusiasm with implementing the new UCTD system and Russel Spiers (NDBC) and James Coleman (NDBC) for their collaboration and hardwork.

Appendix I: Stratus 7 Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. Stratus 7 MOORED STATION NO. 1176

Launch (anchor over)

Date (day-mon-yr) 10/16/2006 Time 17:51:00 UTC

Latitude (N/S, deg-min) 19° 45.320' Longitude (E/W, deg-min) ~~19 45.320~~ -85° 31.75

Deployed by Lord, Weller Recorder/Observer Sebastien Bigorre

Ship and Cruise No. R/V Ron Brown Intended Duration 12 months

Depth Recorder Reading 4441 m Correction Source Matthew's table

Depth Correction 5m Matthew's table m

Corrected Water Depth 4446 m Magnetic Variation (E/W) E 7.6833°

Argos Platform ID No. Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 19° 45.2852' S Long. (E/W) 85° 31.9272' W

Acoustic Release Model

Release No. 32481 / 32478 Tested to 500, 1500 m

Receiver No. Release Command 132132 / 132043

Enable 114617 / 114442 Disable 114634 / 114461

Interrogate Freq. 11 kHz Reply Freq. 12 kHz

Recovery (release fired)

Date (day-mon-yr) 10/29/2007 Time 10:57 UTC

Latitude (N/S, deg-min) 19° 45.245' S Longitude (E/W, deg-min) 85° 31.734' W

Recovered by Lord, Weller Recorder/Observer Galbraith

Ship and Cruise No. RV Ron Brown Actual duration days

Distance from actual waterline to buoy deck m

1

STRATUS 7 - 1176

Surface Components

Buoy Type Foam Color(s) Hull Yellow Tower White

Buoy Markings If found contact Woods Hole Oceanographic Woods Hole MA 02543 USA 508 548 1401

Surface Instrumentation

Item	ID #	Height*	Comments
HRH	232	223	System #1
BPR	207	237.5	
WND	222	273	
PRC	205	241	
LWR	214	283	
SWR	219	282	
SST	1727	-151	
Logger	L-04		
PTT# 18171	27919		
	27920		
	27921		
HRH	231	223	System #2
BPR	217	237	
WND	215	271	
PRC	208	241	
LWR	218	283	
SWR	212	282	
SST	1835	-151	
Logger	L-15		
PTT#12789	27916		
	27917		
	27918		
HRH	216	194.5	Stand alone
LASCAR	3	168.5	Stand alone
LASCAR	4	213	Stand alone

*Height above buoy deck in centimeters

2

STRATUS 7 1176

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
TR-1050	12707	*-12.5	* from top of float
SBE-39	72	*5.5	
pCO_2	0011		
Beacon	104		Subsurface Argos ID 24576

†Depth below buoy deck in centimeters.

3

Moored Station Number STRATUS 7-1176

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1	0.22	3/4" chain							BUOY SECURED ON DECK 17:00
2		XR 420	10514	12:44:49	buoy in water		2	1705 -	
3	0.37	3/4" chain							
4		SBE37	1325	12:44			3.7	1711	
5	1.95	3/4" chain							
6		SBE 37	1326	12:24:50 ~~12:23:30~~			7	1711	
7	1.72	3/4" chain							
8		Aanderaa	13	12:22			10	1713	heads up
9	3.66	3/4" chain							
10		Nortek	2128	12:19:30			15	1715	heads up termination only
11		SBE37	1328	12:19:30			16	1715	
12	2.63	3/4" chain							
13		Aanderaa	78	12:17:30			20	1718	heads up
14	3.66	3/4" chain							
15		SBE 39	476	12:15:30			25	1719	FISHING LINE
16	3.66	3/4" chain							
17		SBE 37	1329	12:14			30	1723	
18	1.20	3/4" chain							
19		Aanderaa	79				32.5	1724	heads up
20	1.20	3/4" chain							
21		SBE 39	477				35	1724	
22	1.20	3/4" chain							

STRATUS 7 - 1/76

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		SBE 37	1330				37.5	1726	
24	1.20	3/4" chain							
25		SBE 37	1906				40	1726	
26	~~5.75~~ 3.25	3/4" wire							
27		VMCM	003		rubber band ✓ · Spin 12:05:31		45	1624	
28	2.38	3/4" chain							
29		Sontek	D208	12:58:50			50	1621	heads down
30	3.66	3/4" chain							
31		VMCM	004	13:03	rubber band ✓ · Spin 12:58:50		55	1618	FISHING LINE IN PROPS
32	5.25	7/16" wire							
33		SBE 37	1908	13:06:30			62.5	~~1613~~ ~~1613~~	FISHING LINE ~~lots of~~
34	6.2	7/16" wire							
35		SBE 39	48	13:11:30	rain started		70	1613	lots of fishing gear
36	6.2	7/16" wire							
37		SBE 39	49	13:14:25			77.5	1610	
38	6.2	7/16" wire							
39		SBE 37	1909	13:16:15			85	16:07	
40	6.2	7/16" wire							
41		SBE 39	102	13:[illegible]:40			92.5	1605	
42	2.40	3/4" chain							
43		SBE 37	2012	13:[illegible]:46			96.3	1603	SOME GOOSE NECKS INSIDE BASKET CASE
44	2.40	3/4" chain							
45		SBE 39	103	13:[illegible]			100	1600	FISHING LINE ON INSTRUMENT

5

Moored Station Number STRATUS 7 1/76

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	13.75	7/16" wire							
47		SBE 39	276	13:30:31			115	1555	FISHING LINE INSIDE (PHOTOGRAPHED)
48	13.75	7/16" wire							
49		SBE 37	2015	13:33:00			130	1552	
50	3.66	3/4" chain							
51		RDI	12~~87~~ 18	13:34:55			135	1549	FISHING LINE ON CAGE BUT NOT INSIDE
52	8	7/16" wire							
53		VMCM	009	13:37:25	rubber band. Spin ✓ 13:35:36		145	1544	PROPS SPINNING FREELY
54	12.8	7/16" wire							
55		SBE 16	146	13:40:10			160	1541	Some BARNACLES
56	13.5	7/16" wire							fishing line ↑
57		SBE 39	284	13:42:00			175	1537	
58	5.75	7/16" wire							
59		VMCM	013	13:43:54	rubber band. Spin ✓ 13:41:40		182.5	1534	
60	5.75	7/16" wire							
61		SBE 16	991	13:47:46			190	1531	NO POISON PLUGS
62	28.5	7/16" wire							
63		SBE 16	1873	13:51:44			220	1527	
64	13	7/16" wire							
65		VMCM	016	13:54:20	rubber band. Spin ✓ 13:51:00		235	1524	PROPS SPINNING
66	13	7/16" wire							
67		SBE 16	1875	13:59:22 ✓			250	1520	POISON PLUGS MISSING

STRATUS 7 - 1176

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
68	38	3/8" wire							
69		VMCM	061	14:02:50	rubber band. spin 13:58:51		290	1515	PROPS GOOD
70	18	3/8" wire							
71		SBE 16	1881	14:05:20			310	1511	
72	38	3/8" wire							
73		VMCM	062	14:08:55	rubber band. spin 14:05:10		350	1505	props spinning well
74	500	3/8" wire							
75		SBE 39	719	14:10			400	1503	clamped
76		SBE 39	720	14:12:48			450	1501	clamped
77		VMCM	083	14:26:50	rubber band. Spin 14:15:00		852	1447	props spinning freely BANDS ON 14
78	500	3/8" wire			end of wire in water @ 14.40			1431 -	
79	500	3/8" wire		1050L				1416	
80	100	3/8" wire						1412	one piece, wrapped terminat.
81	200	7/8" ~~wire~~	nylon	15:05					
82	150	7/8" ~~wire~~	nylon	15:14				1355 -	Is this nylon? Yes!
83	1500	7/8" nylon						1318 -	one piece, spliced at sea
84	100	1" nylon						1315	
85	1500	1 1/8" poly		16:45 end in water					
86		17" glass balls		17:17				1200 - 1213	
87	5	1/2" chain							
88		release		17:40				12:12	Dualed: EGG 8242 IN W...
89	5	1/2" chain							
90	20	1" Samson nystron							

7

Moored Station Number STRATUS 7 #1176

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
91	5	1/2" chain							
92		Anchor		17:51:00					Wet Wt = 8000 lbs Air Wt = 9300 lbs
93									
94									
95									
96									
97									
98									
99									

Date/Time	Comments

03-G0463

Appendix II: Stratus 8 Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. Stratus 8 MOORED STATION NO. 1193

Launch (anchor over)

Date (day-mon-yr) 27-OCT-2007 Time 18:27 UTC

Latitude (N/S, deg-min) 19°37.355 S Longitude (E/W, deg-min) 85 22.536 W

Deployed by LORD Recorder/Observer GALBRAITH

Ship and Cruise No. RON BROWN Intended Duration 12 MONTHS

Depth Recorder Reading 4448.02 m Correction Source MATTHEWS TABLE

Depth Correction 5 m SEABEAM/SEA SURVEY

Corrected Water Depth 4453.02 m Magnetic Variation (E/W) ______

Argos Platform ID No. ______ Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 19° 37.2147 Long. (E/W) 85° 22.7262

Acoustic Release Model 8242 XS

Release No. 30846 / 31269 Tested to ______ m

Receiver No. 18156 Release Command 151376 / 444155

Enable 166561 / 460272 Disable 166603 / 460303

Interrogate Freq. 11 Reply Freq. 12

Recovery (release fired)

Date (day-mon-yr) ______ Time ______ UTC

Latitude (N/S, deg-min) ______ Longitude (E/W, deg-min) ______

Recovered by ______ Recorder/Observer ______

Ship and Cruise No. ______ Actual duration ______ days

Distance from actual waterline to buoy deck ______ m

1

STRATUS 8 #1193

Surface Components

Buoy Type Foam 2.7m Color(s) Hull Yellow Tower White

Buoy Markings ON HATCH: IF FOUND CONTACT WOODS HOLE OCEANOGRAPHIC WOODS HOLE
ON SIDE WHOI 508-457 1401 USA -50- -60 - -70 IF FOUND ADRIFT

Surface Instrumentation

Item	ID #	Height*	Comments
HRH	222	230	System #1
BPR	502	234	
WND	Sonic 203	280	
PRC	502	240	
LWR	505	282	
SWR	214	282	
SST	1834		
Logger	L-01		FIRMWARE LOGR53 V2.70
PTT # 14612			IDS 24337, 27970, 27971
HRH	225	230	System #2
BPR	210	235	
WND	211	272	
PRC	506	240	
LWR	502	282	
SWR	223	282	
SST	1840		
Logger	L-02		
PTT # 14709			IDS 9805, 9807, 9811
WND	343	272	Stand alone

*Height above buoy deck in centimeters

2

STRATUS 8 1193

Subsurface Instrumentation on Buoy and Bridle			
Item	ID #	Depth†	Comments
SBE 39	1446		floating SST
TR 1050	10983		floating SST
pCO2			
Argos beacon SN 22			Subsurface Argos ID# 11427
WAMDAS			WAVE PACKAGE, NDBC STATION WHOI I
			IRIDIUM MODEM 24536

†Depth below buoy deck in centimeters

3

Moored Station Number 1193 Stratos 8

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	NOMINAL Depth (m)	Time Back	Notes
1		BUOY		1224					
2	.22	3/4" CHAIN							
3		SBE 37	1901	1223	MICROCAT		2		
4		XR420	10515						
5	.37	3/4" CHAIN							
6		SBE 37	1902	1211			3.7		
7	1.95	3/4" CHAIN							
8		~~ADCP~~ SBE37	1903	1207			7		
9	1.95	3/4" CHAIN							
10		ADCP	333	1207	NORTEK ? HEAD UP		10		
11	3.66	3/4" CHAIN							
12		ADCM	1666	1205	NORTEK HEADS UP		15		
13		SBE 37	1905	1205			16		
14	2.55	3/4" CHAIN							
15		ADCM	1688	1204	NORTEK		20		
16	3.66	CHAIN ~~SBE 39~~							
17		SBE 39	203	1202			25		
18	3.66	CHAIN							
19		SBE 37	1907	1200			30		
20	.9	CHAIN							
21		ADCM	D193	1200	SONTEC		33		
22	1.2	CHAIN							

1193 - Stratus 8

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		SBE 39	0721	1158			35		
24	3.66	CHAIN							
25		SBE 37	1910	1157			40		
26	366	CHAIN							
27		ADCM	2064	1155			45		
28	8.75	WIRE							
29		ADCM	2082	1238			55		
30	6.1	WIRE							
31		SBE 37	1912	1242			62.5		
32	21.1	WIRE W/							
33		SBE 39	3423	1244			70		
34		SBE 39	3434	1245			77.5		
35		SBE 37	2011	1250			85		
36	13.3	WIRE							
37		SBE 39	3435	1251			92.5		
38		VMCM	10	1258	1255 BANDS OFF		100		
39	27.8	WIRE							
40		SBE 39	3436	1300			115		
41		SBE 37	3639T	1304			130		
42	3.66	~~WIRE~~ CHAIN							
43		ADCP	1220	1306			135		
44	8	WIRE							
45		VMCM	29	1310	BANDS OFF 1308 (CASE LABELED #76)		145		

Moored Station Number 1193 - Stratus 8

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	12.8	WIRE							
47		SBE 16	927	1314			160		
48	21.3	WIRE							
49		SBE 39	3437	1315			175		
50		VMCM	30	1319	BANDS OFF "ABOUT" 1317		183		
51	4.8	~~SBE 16~~ WIRE							
52		SBE 16	928	1323			190		
53	28.5	WIRE							
54		SBE 16	993	1326			220		
55	13	WIRE							
56		VMCM	57	1330	BANDS OFF 1328		235		
57	13	WIRE							
58		SBE 16	994	1336			250		
59	38	WIRE							
60		VMCM	58	1340	1337 BANDS OFF		290		
61	18	WIRE							
62		SBE 16	1877	1346			310		
63	38	WIRE							
64		VMCM	66	1352	1348 BANDS OFF		350		
65	500	WIRE							
66		SBE 39	3438	1356			400		
67		SBE 39	3439	1359			450		

1193-Stratus 8

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
68		VMCM	68	1433	1432 BANDSAFF		852		
69	500	WIRE			1434-1456				
70	200	WIRE		1457-					
71		VMCM	76	1510	1508 BANDSAFF		1555		
72	300	WIRE	NEW	1510-					
73	100	WIRE		1524-					
74	200	NYLON ~~WIRE~~ 7/8		1530-					
75	1650	NYLON 7/8		1543-					
76	100	NYLON 1"							
77	1500	POLYPRO 1 1/8		1620-					
78		GLASSBALLS	85						
79	5	CHAIN 1/2"		1800					
80		RELEASES		1815					
81	5	CHAIN 1/2"							
82	20	NYSTRON 1"		1817					
83	5	CHAIN 1/2"							
84		ANCHOR		1827	-19° 37.355 -85° 22.536				
85									
86									
87									
88									
89									
90									

7

Moored Station Number 1193-Stratus 8

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
91									
92									
93									
94									
95									
96									
97									
98									
99									

Date/Time	Comments
	COUNTING BALLS, DEPLOYMENT NEED 22 CLUSTERS OF 4

03-G0463

Appendix III: SHOA/DART Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. SHOA/DART MOORED STATION NO. II
yellow deck, red hull, white tower . SHOA TSUNAMI

Launch (anchor over)

Date (day-mon-yr) 10/23/2006 Time 13:59:30 UTC

Latitude (N/S, deg-min) 19° 36.149' Longitude (E/W, deg-min) ~~75~~ 74° 46.740'

Deployed by ______ Recorder/Observer Bigorre

Ship and Cruise No. Ron Brown 06-07 Intended Duration 2 years

Depth Recorder Reading 4945 m Correction Source Nathan's table

Depth Correction 5 m

Corrected Water Depth 4950 m Magnetic Variation (E/W) ______

Argos Platform ID No. ______ Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 19°35'.423 S Long. (E/W) 74° 46' 7904 W

Acoustic Release Model ______

Release No. ~~444130~~, SN# 31268 Tested to ______ m

Receiver No. ______ Release Command 444130

Enable 460234 Disable 460251

Interrogate Freq. 11 kHz Reply Freq. 12 kHz

Recovery (release fired)

Date (day-mon-yr) ______ Time ______ UTC

Latitude (N/S, deg-min) ______ Longitude (E/W, deg-min) ______

Recovered by ______ Recorder/Observer ______

Ship and Cruise No. ______ Actual duration ______ days

Distance from actual waterline to buoy deck 0.40 m

1

Surface Components

Buoy Type DART II Color(s) Hull ________ Tower ________

Buoy Markings ________

Surface Instrumentation

Item	ID #	Height*	Comments
WND	344	245	
LWR	213	232	
SWR	201	231	
Lascar HRH	5	196	
Lascar HRH	6	224	
			recovered ↑

2006

Turned met sensors around after 1 year. Left mooring in place. Boat trip to buoy.

2007

Item	ID #	Height*	Comments
WND	WND 214		
LWR	LWR 208		
SWR	SWR 202		
RH/AT	HRH 502		
[illegible]			

*Height above buoy deck in centimeters

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
TR 1050	12694	120 cm	

†Depth below buoy deck in centimeters

3

4

Moored Station Number DART II

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1	3.5	1" chain							
2		5 ton swivel							
3	0.5	1" chain							
4	700	7/16" wire							
5		XR 420	12942	10:58			10		
6		XR 420	12943	10:58			20		
7		TR 1050	12695	10:58			30		
8		TR 1050	12696	10:58			40		
9		XR 420	12944	10:58			50		
10		TR 1050	12697	10:58			62.5		
11		TR 1050	12698	10:58			77.5		
12		XR 420	12945	11:01			92.5		
13		TR 1050	12699	11:03			115		
14		XR 420	12946	11:06			145		wire repaired below
15		TR 1050	12700	11:14			175		
16		TR 1050	12701	11:17			220		
17		TR 1050	12702	11:22			250		
18		TR 1050	12703	11:31			310		wire repaired above
19	1185	nylon							1" to 7/8" to 3/4" spliced
20	595	3/4" nylon	Y369						
21	593	3/4" nylon	Y360						
22	580	3/4" nylon	Y379						

Item No.	gth (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23	580	3/4" nylon	Y331						
24	575	3/4" nylon	Y358						
25		3/4" nylon							
26	1	1/2 trawl chain							
27		5 ton swivel							
28		Edgetech release	31268	13:30					
29	1	1/2 trawl chain							
30	20	nystron							
31	4	1/2" chain							
32		anchor					4980		wet wt 4900 lbs air wt 6850 lbs
33									
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									

5

Appendix III: STRATUS 2007 SBE19 CTD Casts

Cast No.	Date	Time	Latitude/Longitude	Depth (meters)	Notes
1	Oct 22, 2007	22:09:43	12 26.659 74 51.181	4486	By SHOA DART Buoy
2	Oct 26, 2007	20:07:12	19 50.945 85 15.479	4000	By Stratus 7
3	Instrument failure				
4	Oct 28, 2007	19:39:45	19 42.930 85 33.327	200	UCTD Comparison
5	Oct 30, 2007	20:25:00	19 42.930 85 33.327	4000	
6	Oct 30, 2007	22:56:00	19 34.081 85 21.990	4000	
7	Oct 30, 2007	24:00:00	19 34.080 85 21.089	30	XR-420 comparison

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16. Abstract (Limit: 200 words)

The Ocean Reference Station at 20°S, 85°W under the stratus clouds west of northern Chile is being maintained to provide ongoing climate-quality records of surface meteorology (air-sea fluxes of heat, freshwater, and momentum), and of upper ocean temperature, salinity, and velocity variability. The Stratus Ocean Reference Station (ORS Stratus) is supported by the National Oceanic and Atmospheric Administration's (NOAA) Climate Observation Program. It is recovered and redeployed annually, with cruises between October and December. During the October 2007 cruise on the NOAA ship Ronald H. Brown to the ORS Stratus site, the primary activities were recovery of the Stratus 7 WHOI surface mooring that had been deployed in October 2006, deployment of a new (Stratus 8) WHOI surface mooring at that site; in-situ calibration of the buoy meteorological sensors by comparison with instrumentation put on board the ship by staff of the NOAA Earth System Research Laboratory (ESRL); and observations of the stratus clouds and lower atmosphere by NOAA ESRL. Meteorological sensors on a buoy for the Pacific tsunami warning system were also serviced, in collaboration with the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA). The DART (Deep-Ocean Assessment and Reporting of Tsunami) carries IMET sensors and subsurface oceanographic instruments. A new DART II buoy was deployed north of the STRATUS buoy, by personnel from the National Data Buoy Center (NDBC) Argo floats and drifters were launched, and CTD casts carried out during the cruise. The ORS Stratus buoys are equipped with two Improved Meteorological (IMET) systems, which provide surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming longwave radiation, precipitation rate, and sea surface temperature. Additionally, the Stratus 8 buoy received a partial pressure of CO_2 detector from the Pacific Marine Environmental Laboratory (PMEL). IMET data are made available in near real time using satellite telemetry. The mooring line carries instruments to measure ocean salinity, temperature, and currents. The ESRL instrumentation used during the 2007 cruise included cloud radar, radiosonde balloons, and sensors for mean and turbulent surface meteorology. Finally, the cruise hosted a teacher participating in NOAA's Teacher at Sea Program.

17. Document Analysis a. Descriptors

Stratus
upper ocean
air-sea interaction

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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